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WATER SUPPLY AND WATER QUALITY CONTROL STUDY, KAW RESERVOIR, ARKANSAS RIVER BASIN, KANSAS AND OKLAHOMA

Public Health Service
Dallas, Texas

July 1965

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WATER SUPPLY
AND
WATER QUALITY CONTROL STUDY
KAW RESERVOIR, ARKANSAS RIVER BASIN
KANSAS AND OKLAHOMA

Study of Needs and Value of Storage
for Municipal and Industrial Water
Supply and Water Quality Control

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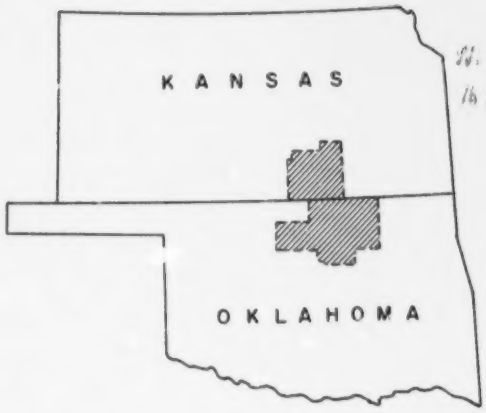

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

JULY 1965

WATER SUPPLY

AND

WATER QUALITY CONTROL STUDY

KAW RESERVOIR, ARKANSAS RIVER BASIN

KANSAS AND OKLAHOMA

Abstract

An investigation was carried out which discloses the need for and value of storage for municipal, industrial and water quality control purposes in the proposed Kaw Reservoir. The study reveals a future need for water supply within the project vicinity exceeding the maximum potential yield of the proposed reservoir. A future need is also indicated for water quality control storage in the reservoir to maintain satisfactory stream quality for a distance of approximately 75 miles below the damsite. Projected municipal and industrial water supply needs are based on economic and demographic studies of the study area's potential.

Prepared for

DEPARTMENT OF THE ARMY

U.S. Army Engineer District

Tulsa, Oklahoma

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

JULY 1965

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	vi
I. INTRODUCTION	
Request and Authority	I-1
Purpose and Scope	I-1
Acknowledgments	I-1
II. SUMMARY OF FINDINGS AND CONCLUSIONS	
Summary of Findings	II-1
Conclusions	II-2
III. DESCRIPTION OF PROJECT	
Location and Features	III-1
Streamflow	III-1
Water Quality	III-2
IV. STUDY AREA DESCRIPTION	
Location and Boundaries	IV-1
Climate	IV-1
Geography	IV-1
Principal Communities and Industries	IV-1
V. WATER RESOURCES OF THE STUDY AREA	
General	V-1
Quantity of Water Available	V-1
Quality of Water Available	V-3

TABLE OF CONTENTS (Continued)

		Page
VI.	THE ECONOMY	
	General	VI-1
	Present	VI-1
	Future	VI-9
VII.	WATER REQUIREMENTS	
	Municipal Water Use	VII-1
	Industrial Water Use	VII-1
	Rural Water Use	VII-1
	2070 Water Requirements	VII-2
VIII.	WATER QUALITY CONTROL	
	Allowances for Streamflow	VIII-3
	Annual Draft-On-Storage Needed to Control Water Quality	VIII-3
	Water Quality Control Needs in the Wichita Area	VIII-4
IX.	WATER SUPPLY AND WATER QUALITY CONTROL PLAN	
	General	IX-1
	Alternatives	IX-1
X.	BENEFITS	
	Municipal and Industrial Water Supply Benefits	X-1
	Water Quality Control Storage Benefits	X-1
XI.	BIBLIOGRAPHY	XI-1

TABLE OF CONTENTS (Continued)

Page

APPENDIX

A. Analysis of Mineral Quality - Kaw Reservoir. . A-1

B. Water Quality Control Needs--Method of Analysis B-1

C. Benefit Calculations C-1

LIST OF TABLES

Number	Title	Page
III-1	Principal Features - Kaw Reservoir, Arkansas River Basin	III-1
IV-1	Population of Principal Communities	IV-2
V-1	Existing Ground Water Supplies in the Study Area	V-2
V-2	Ground Water Quality in the Study Area	V-4
V-3	Surface Water Quality in the Study Area	V-5
VI-1	Per Capita Disposable Personal Income for the Study Area, Kansas, Oklahoma, and the U.S., 1940, 1950, and 1960	VI-3
VI-2	Labor Force Distribution in the Study Area, Oklahoma, Kansas, and the United States, 1940, 1950, 1960	VI-4
VI-3	Summary of Agricultural Statistics for the Study Area, Oklahoma, Kansas, and the U.S., 1944, 1949, 1954, and 1959	VI-6
VI-4	Value of Minerals Produced in the Study Area, Oklahoma, Kansas, and the U.S.--1953-1960	VI-7
VI-5	Value Added by Manufacturing in the Study Area, Oklahoma, Kansas, and the Nation, 1939, 1947, 1954, and 1958	VI-8
VI-6	Distribution of Manufacturing Labor Force for the Nation and the Study Area--1960	VI-9
VI-7	Population Trends of the Study Area 1920-1960	VI-10
VI-8	Distribution of Projected Study Area Employment	VI-11
VI-9	Population Projections for the Study Area 2020 and 2070	VI-12
VII-1	Projected 2020 Industrial Water Requirements by Industry for the Study Area	VII-3
VIII-1	Annual Draft-On-Storage Needed for Water Quality Control Below Kaw Reservoir	VIII-3

LIST OF TABLES (Continued)

Number	Title	Page
IX-1	Study Area Municipal Water Supplies.	IX-2
IX-2	Assumed Plans for Meeting Projected Study Area Water Requirements	IX-3
	APPENDIX	
B-1	Natural Monthly Discharge - Kaw Damsite (Condition A).	B-3
B-2	Natural Monthly Discharge - Kaw Damsite (Condition B).	B-4
B-3	Minimum Monthly Streamflow Required for Water Quality Control Below Kaw Reservoir.	B-5
B-4	Supplemental Water Quality Control Requirements Arkansas River Below Kaw Reservoir	B-6
B-5	Plotting Positions in Percent.	B-7
B-6	Annual Draft-On-Storage Needed for Water Quality Control Below Kaw Reservoir.	B-8

LIST OF FIGURES

Number	Title	Following Page
III-1	Location Map	C-2
VI-1	Population Trends and Projections	VI-11
	APPENDIX	
A-1	Dissolved Solids - Stream Discharge Relationship.	A-2
A-2	Dissolved Solids Concentration Vs. Streamflow.	A-2
A-3	Kaw Reservoir Dissolved Mineral Concentration Duration Curves	A-2
B-1	Natural Annual Mean Discharge Frequency (Kaw Damsite) - Condition A	B-1
B-2	Natural Annual Mean Discharge Frequency (Kaw Damsite) - Condition B	B-1
B-3	Supplemental Water Quality Control Requirements - Arkansas River Below Kaw Reservoir (Yr 2020) Condition "A"	B-1
B-4	Supplemental Water Quality Control Requirements - Arkansas River Below Kaw Reservoir (Yr 2070) Condition "A"	B-1
B-5	Supplemental Water Quality Control Requirements - Arkansas River Below Kaw Reservoir (Yr 2020) Condition "B"	B-1
B-6	Supplemental Water Quality Control Requirements - Arkansas River Below Kaw Reservoir (Yr 2070) Condition "B"	B-1

I. INTRODUCTION

Request and Authority

In a letter dated August 30, 1963, the Corps of Engineers, Tulsa District, requested that the Public Health Service ". . . make the studies needed to complete a detailed investigation of the quality of flows, the municipal, industrial, and quality control needs of the area which might be served by the Kaw Reservoir, and the value of water for these uses."

This study has been made in accordance with: (1) a Memorandum of Agreement between the Department of the Army and the Department of Health, Education, and Welfare, dated November 4, 1958 relative to Title III of the Water Supply Act of 1958 as amended; and (2) the Federal Water Pollution Control Act as amended (33 U.S.C. 466 et seq.).

Purpose and Scope

The purpose of this study was to determine water requirements to the years 2020 and 2070 for municipal and industrial and water quality control purposes in the 10-county area lying within north-central Oklahoma and south-central Kansas which could be served by Kaw Reservoir. A plan of how these projected needs may be met is given, and an estimate of the average annual value of benefits which could be ascribed to storage allocated to these purposes is evolved from projected economic developments and anticipated needs for water supply and stream quality preservation.

Acknowledgments

The assistance and cooperation of agencies and individuals who aided in the assembly of data for this report are gratefully acknowledged. Special appreciation is expressed to the following:

Oklahoma Water Resources Board
Oklahoma State Department of Health
Kansas Water Resources Board
Kansas State Department of Health
Officials of cities in the study area
Representatives of industry in the study area

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. Kaw Reservoir is an authorized Corps of Engineers multipurpose project which will be located on the main stem of the Arkansas River near the Oklahoma-Kansas state line. The project is designed for flood control, conservation, recreation, and fish and wildlife uses.

2. The study area comprises 10 counties: Cowley, Butler, Sedgwick, and Sumner Counties in Kansas, and Garfield, Noble, Payne, Pawnee, Osage, and Kay Counties in Oklahoma. Situated in the prairie grasslands and red prairies of north-central Oklahoma and south-central Kansas, the study area covers an area of about 11,000 square miles.

3. The study area population in 1960 was 646,000. Approximately 495,000 or 77 percent of the area's population were residing in or near the study area's 22 urban communities. Total 1960 rural population in the study area amounted to 151,000.

4. Municipal water use and waste production in the study area is largely centered at Wichita, Eldorado, and Arkansas City, Kansas, and Enid, Ponca City, and Stillwater, Oklahoma. Principal sources of industrial water use and waste discharge are the oil, gas, and salt recovery industries.

   Total municipal water use in the study area presently averages about 60 million gallons per day (mgd). Reported municipal waste discharges to study area streams in 1962 were 49 mgd, almost all of which received secondary treatment. The estimated population equivalent (PE) of the above discharges was 130,000.

5. Estimated safe yields of present municipal water supplies in the study area total 267 mgd.

6. Water impounded by Kaw Reservoir will be of marginal quality until measures are taken to control upstream mineral pollution. During most periods of the year, mineral solids can be expected to exceed the upper limits of the Public

Health Service Drinking Water Standards-1962 for finished waters. With recommended control of upstream mineral pollution, water impounded in the reservoir will be of acceptable quality for municipal and for most industrial purposes.

Conclusions

1. To meet anticipated water supply needs, careful planning for efficient development of all of the study area's water resources is essential. It is anticipated that extensive efforts will be made toward control of natural and manmade mineral pollution in the study area within the next few years. As an outgrowth of these efforts, it is expected that the mineral quality of waters flowing into Kaw Reservoir will be substantially improved, thereby increasing the attractiveness of the reservoir as a municipal water supply source.

2. The study area's population is expected to grow to 1,980,000 by the year 2020, with 1,850,000 residing in urban areas and 130,000 in rural areas. The population potential for this area by the year 2070 is estimated in the neighborhood of 4,000,000. Projected 2070 urban and rural populations are 3,875,000 and 125,000, respectively.

3. Future needs for 566 mgd of water supply storage are expected to occur in the areas of Wichita, Kansas, and Ponca City and Stillwater, Oklahoma. The project which has a municipal and industrial water supply yield of 167 mgd could supply all of the water needs projected for communities in Oklahoma, and a substantial portion of the projected water needs of Wichita, Kansas, as presented in the water supply plan, table IX-2.

4. The average annual benefit to municipal and industrial water supply storage in Kaw Reservoir is estimated at $1,753,000 with 1985 the anticipated year of first need. The 1970 worth of this value is $1,105,000.

5. To prevent nuisance conditions from occurring in the Arkansas River for a distance of about 75 miles below the proposed Kaw Reservoir, and maintain dissolved oxygen levels in the stream which will support fish life and encourage recreation and other

uses of the stream will require an annual draft-on-storage of 13,000 acre-feet per year by the year 2070.

6. The average annual benefit to water quality control storage in Kaw Reservoir for downstream flow regulation is estimated to be $503,000 including operation and maintenance with 1990 the anticipated year of first need. The 1970 present worth of this value is $238,000.

7. Benefits to water quality control storage in Kaw Reservoir will be widespread in scope. These benefits from storage for water quality control will be realized only if adequate treatment is provided waste discharged to affected stream reaches.

III. DESCRIPTION OF PROJECT

Location and Features

The recently authorized Kaw Reservoir will be a multiple-purpose project, designed for flood control, conservation, recreation, and fish and wildlife. The Kaw damsite is located on the main stem of the Arkansas River at river mile 653.7, about 8 miles east of Ponca City in northeastern Oklahoma. (See the location map, figure III-1, at the back of this report.) During periods when the flood control pool is full, headwaters of the reservoir will extend for a few miles into Kansas.

Principal features of the reservoir are shown in table III-1.

Table III-1

Principal Features - Kaw Reservoir
Arkansas River Basin

Stream	Arkansas
Miles above mouth	653.7
Drainage Area, Sq. Mi.	
Total	46,531
Contributing to flood of record flows	7,251
Contributing to spillway design flood	8,995
Purposes	Flood control, conservation, recreation, and fish and wildlife
Pool elevations, ft., m.s.l.	
Flood control pool	1,044.5
Conservation Pool	1,010.0
Storage allocations, acre-feet a/	
Flood control	835,000
Conservation	
Water supply	171,200
Water quality control	31,800
Inactive	0
Water supply yield, mgd	167
Water quality control yield, mgd	39

a/ After 100 years sediment

Source: Corps of Engineers

Streamflow

Information on discharge for the Arkansas River in the immediate vicinity of the Kaw damsite is not available. However, runoff from all but about 1,000 square miles of the drainage area above the damsite can be measured by two upstream gaging stations, Arkansas

City and Winfield, Kansas. The Arkansas City station [a/] is located on the main stem of the Arkansas River (river mile 701.4) about 8 miles above the Kansas State line. The Winfield station [b/] is located at river mile 24.8 on the Walnut River, a major tributary to the Arkansas, with confluence immediately downstream from Arkansas City. Streamflow in the study area reach of the Arkansas River fluctuates widely. Stream velocities range from moderately fast during periods of high flow to slow or almost no flow at all on other occasions. The river channel has a broad, sandy bed ranging between 400 and 2,500 feet in width, with low banks 6 to 15 feet high. In places the river divides into numerous channels, producing a braided pattern which is indicative of a depositing stream.

Water Quality

As shown by table V-3, dissolved minerals in waters flowing into the reservoir (based upon chemical quality records at Arkansas City and Winfield) range from fair to poor. It is expected that the chemical quality of mixed waters from the two sources (Walnut and Arkansas Rivers) could be classified as marginal with dissolved solids and chlorides exceeding upper limits of the Public Health Service Drinking Water Standards-1962 [5/] a large percent of the time. Sulfate concentrations would be within the above limits most of the time.

An analysis of dissolved mineral concentrations (including total solids, chlorides and sulfates) expected to exist in the reservoir was made using water quality records at Arkansas City and Winfield. Reservoir dissolved mineral quality duration curves developed from these data are shown (solid lines) on figure A-3 (Appendix A).

---

a/ Discharge records from 1902 to 1906, and 1921 to 1963 are available. [1-4]
b/ Discharge records from 1921 to 1963 are available. [1-4]

IV. STUDY AREA DESCRIPTION

Location and Boundaries

Boundaries of the study area are shown in figure III-1 at the back of this report. As shown in figure III-1, the area investigated in this report consists of Garfield, Noble, Payne, Pawnee, Osage, and Kay Counties in Oklahoma, and Cowley, Butler, Sedgwick, and Sumner Counties in Kansas. These 10 counties lie within the Arkansas River basin (near the mid-point of the basin) and compose the area which can potentially be benefited by the recently authorized multipurpose Kaw Reservoir at river mile 653.7 on the main stem of the Arkansas River.

Climate

The study area has a moist, subhumid climate with an average annual precipitation varying from about 38 inches in the east to about 28 inches in the west. Precipitation is characterized by intense rainstorms of short duration with the maximum occurring in the late spring and the minimum during the winter months. Flood and extended droughts are common, as evidenced by the occurrence of three severe droughts during the past 70 years (1892-1894, 1934-1946, and 1952-1956).

The mean annual temperature of the Kansas portion of the study area is 57°F, with monthly mean temperatures varying from 32°F in January to 81°F in July. The Oklahoma portion has a mean annual temperature of about 61°F with a mean of 37°F in January and 83°F in July.

Geography

Geographically, the Kansas and Oklahoma land area portions of the study area consist of prairie grasslands and reddish prairies. The elevation of the Kansas section varies from 1,100 to 1,800 feet, and the Oklahoma section varies from 600 to 1,400 feet above mean sea level. The eastern part of the study area is characterized by rolling, undulating uplands composed of rugged stony hills which are referred to as the Flint Hills. The central and western part of the study area is characterized by level to hilly uplands. Principal streams in the study area, besides the Arkansas River, include the Walnut and Ninnescah Rivers in Kansas, and the Salt Fork of the Arkansas River and Black Bear Creek in Oklahoma, with the Chikaskia River being common to both States.

Principal Communities and Industries

Essentially, the study area is rural in character except in and around Wichita. The most conspicuous feature of the area's

population trend is that it reflects the national condition of rural area decline and urban area increase which has been brought about due to drought, soil erosion, farm consolidation, and technological progress.

The following table IV-1 shows the population of communities in the study area with a population of 2,500 or more. Populations shown are for the corporate city limits only, with the urban fringe areas excluded.

Table IV-1

Population of Principal Communities

State	County	Town	1960 Population
Kansas	Sedgwick	Wichita	254,698
		Haysville	5,836
		Derby	6,458
		Valley Center	2,570
		Park City	2,687
		Mulvane	2,981
	Sumner	Wellington	8,809
	Butler	Augusta	6,434
		El Dorado	12,523
	Cowley	Arkansas City	14,262
		Winfield	11,117
Oklahoma	Garfield	Enid	38,859
	Kay	Ponca City	24,411
		Blackwell	9,588
		Tonkawa	3,415
	Noble	Perry	5,210
	Payne	Stillwater	23,965
		Cushing	8,619
	Pawnee	Cleveland	2,519
	Osage	Pawhuska	5,414
		Hominy	2,866
		Tulsa	3,414

Source: Bureau of the Census

Industry in the study area is now oriented around the production of civilian and military aircraft, petroleum and natural gas extraction and agriculture. The latter is the leading and most basic industry in the area.

V. WATER RESOURCES OF THE STUDY AREA

General

Because of undesirable mineral concentrations, the use of surface water in the study area has generally been limited to small tributary impoundments. The importance of ground water to the region's economy is, therefore, very evident. Approximately 80 percent of reported study area water use in 1960 came from ground water supplies. In some instances where surface water is used, ground water is combined with the surface water to achieve a satisfactory finished water quality.

Quantity of Water Available

Ground Water

Ground water is found in fairly large quantities at several scattered locations in and bordering the study area. The best sources of ground water in the region are sands and gravels of the Quaternary System, which yield moderate to large supplies of water, principally from the alluvial aquifers. Yields per well in these aquifers range from 50-500 gallons per minute (g.p.m.) in the southern portion of the study area to better than 500 g.p.m. along the river valley of the main channel and in the northwestern section of the study area.

The largest major ground water aquifer serving the study area is the Equus Beds, a formation north of Wichita, Kansas, underlying portions of Sedgwick County and three counties outside of the study area. This aquifer, which supplies the water needs of Wichita, Kansas, and a number of smaller towns in the vicinity, is believed to contain 15 million acre-feet of storage. Present withdrawals from the Equus Beds are estimated in the neighborhood of 100,000 acre-feet per year. 6/ Although a slight overall decline in the water table has been evidenced since 1940, water in the beds is believed transient 6/ and a renewable resource. Some investigators have placed the average recharge rate of the aquifer in the neighborhood of 20 percent of the average annual precipitation. It has been estimated that during the wet period 1948-1952, less than 1 percent of water pumped from the Equus Beds came from storage.

Based on estimated safe yields of the aquifer (which takes into consideration the large number of users), the city of Wichita is planning to use a maximum of about 65,000 acre-feet of water per year from the Equus Beds. 6/

Significant ground water supplies, though of poor chemical quality, are also available in the alluvial aquifer of the Arkansas River near Wichita. It is estimated the present stand-by wells in

this aquifer are capable of yielding about 34,000 acre-feet of water per year. 6/

Storage-yield information is generally not available for other aquifers in the study area except for the Cimarron Terrace deposits near Enid, Oklahoma.

These deposits, lying in the southwestern portion of Garfield County and extending into three counties outside of the study area, contain an estimated 830,000 acre-feet of water. 7/ About 30 percent of the aquifer lies within the study area. It is believed that a safe yield of about 33,000 acre-feet per year of ground water is available in well fields owned by the city of Enid. 8/ There has been no evidence of aquifer depletion. During the drought period of the mid-1950's, water levels in wells near Enid declined; however, original levels have since been regained. 9/

A summary of existing ground water supplies in the study area is shown in table V-1.

Table V-1

Existing Ground Water Supplies in the Study Area

State	County	Municipality Served	No. Wells	Yield (mgd)
Kansas	Sedgwick	Wichita	91	96 a/
	Cowley	Arkansas City	8	6
		Winfield		3 b/
	Sumner	Wellington		2 b/
Oklahoma	Kay	Ponca City	74	26.6
		Tonkawa	12	1
	Payne	Cushing	9	3
	Garfield	Enid	84	29
		TOTAL		166.6

a/ Includes planned well field expansion and estimated yields of wells in urban areas.

b/ Estimate

Surface Water

Streamflow in the study area consists primarily of storm runoff; however, ground water discharges are important in sustaining flows in most of the study area streams in time of drought and in periods of low precipitation. As indicated in Chapter III, wide fluctuations in streamflow have occurred throughout the study area. At the Arkansas City and Winfield gaging stations located upstream from the Kaw damsite, flows ranging from 103,000 cubic feet per second (cfs)-1 cfs and 105,000 cfs-0 cfs have been recorded respectively, while at the Ralston gaging station downstream from the proposed damsite, maximum and minimum discharges of 179,000 cfs and 14 cfs respectively have occurred. For all of the streams tributary to the Arkansas River in the study area with the exception of the Cimarron River, there have been periods of no flow. The minimum daily discharge of the Cimarron River at Perkins was 0.8 cfs compared to a high of 149,000 cfs.

The Keystone Reservoir and Cheney Reservoir, located in the southeast and northwest corners of the study area respectively are the only major reservoirs in the area. Keystone Reservoir, now nearing completion, is being built primarily for flood control, navigation, and industrial water supply and will contain approximately 2,000,000 acre-feet of storage. Other uses of the reservoir will include hydroelectric power production and recreation. Cheney Reservoir, recently completed, contains approximately 243,000 acre-feet of storage (with a dependable water supply yield of 38 mgd) and is used primarily as a source of municipal and industrial water supply for the city of Wichita, Kansas. The reservoir contains storage for flood control and is also used for recreation, fish and wildlife purposes.

The estimated total yield of the numerous small tributary impoundments in the study area is 62.6 mgd.

Quality of Water Available

Ground Water

A summary of ground water quality in the study area is given in table V-2. As indicated by the table, ground water of good chemical quality is found in areas around Wichita and Enid and in some instances near Wellington. Ground water quality ranging from fair to poor is indicated at other locations. High mineral concentrations in the Arkansas River are reflected in the alluvial ground water supplies of Arkansas City and Ponca City.

Table V-2

Ground Water Quality in the Study Area
(mg/l)

Sampling Point	Date	Chloride (Cl)	Sulfate (SO_4)	Hardness ($CaCO_3$)	Dissolved Solids
Wichita	1950a/	43	54	86	260
Winfield	1951a/	26	81	334	464
Arkansas City	1951a/	162	119	342	706
	1950b/	126	361	701	1,120
Ponca City	1951a/	39	21	172	346
Enid	c/	291	196	522	1,210
Wellington	d/	12	18	94	192
Wellington					

a/ Finished water (composite)
b/ Raw water composite
c/ Wells in Wellington Shale
d/ Wells in Nebraskan Formation

Source: Geological Survey, 10/ Kansas Water Resources Board 11/

Surface Water

The chemical quality of surface waters for major streams in the study area is shown in table V-3.

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Table V-3

Surface Water Quality in the Study Area
(Weighted Monthly Avg. Concentrations in mg/l)

		Dissolved Solids	Chlorides (Cl^-)	Sulfates (SO_4)
LITTLE ARKANSAS RIVER at VALLEY CENTER Period of record - November 1956 to December 1960.	Arith Mean	523	50	150
	Maximum	977	89	385
	Minimum	98	8	18
SOUTH FORK of the NINNESCAH RIVER near MURDOCK Period of record - November 1956 to September 1961.	Arith Mean	694	49	267
	Maximum	1,103	70	500
	Minimum	230	18	52
CHIKASKIA RIVER at CORBIN Period of record - September 1950 to September 1951, December 1956 to September 1961.	Arith Mean	305	49	24
	Maximum	383	80	40
	Minimum	134	13	5
WALNUT RIVER at WINFIELD Period of record - July 1960 to September 1962. Water quality data based on correlation of continuous conductivity measurement with concentrations of chlorides, sulfates, and dissolved solids in weekly grab samples.	Arith Mean	465	115	89
	Maximum	995	300	200
	Minimum	189	34	38
ARKANSAS RIVER at ARKANSAS CITY Period of record - January-May 1907, October 1951 to September 1958, July 1960 to September 1962. Portions of these data are based on correlation of continuous conductivity measurement with concentrations of chlorides, sulfates, and dissolved solids in weekly grab samples.	Arith Mean	1,092	398	171
	Maximum	2,500	1,160	372
	Minimum	315	88	48
ARKANSAS RIVER at RALSTON Period of record - January 1950 to September 1958.	Arith Mean	998	412	143
	Maximum	2,520	1,210	353
	Minimum	322	98	36
CIMARRON RIVER at PERKINS Period of record - October 1952 to September 1959.	Arith Mean	2,995	1,489	233
	Maximum	12,600	6,770	750
	Minimum	565	217	53

Sources: Public Health Service [12] [16], Geological Survey [13], Kansas State Board of Health [14], and Oklahoma Water Resources Board [15]

VI. THE ECONOMY

General

Economic and demographic growth in the study area will be a deciding factor of future needs for municipal and industrial water supply development and water quality control in the area. The economic and demographic data presented herein serve as a basis for estimating future municipal and industrial water use requirements and waste loadings in the study area.

Present

The study area comprises an area of 10 counties, 6 in north-central Oklahoma and 4 in south-central Kansas.

The most conspicuous features of the study area's economy are the prominence of civilian and military aircraft production, petroleum and natural gas extraction in the creation of wealth and employment. Aircraft production, with principal location at Wichita, Kansas, is the largest manufacturing industry in the study area. Petroleum refining and furnishing of supplies for the petroleum industry are also important functions in the larger towns, such as Enid, Ponca City, and Wichita. The economy of these towns (which constitute the study area's major population centers) is further supported by wholesale and retail trade and the processing of farm products.

Agriculture is the leading and most basic industry in the study area. Since rainfall is scarce and variable, drought resistant crops such as wheat and sorghum must be grown. In those areas where the use of large-scale mechanical farm equipment is not practical, cattle production is the most important agricultural activity, with dairying being of significance near Wichita.

Grass fattening of cattle on the superior grazing land offered by the Flint Hills is the leading agricultural activity in the eastern part of the study area. The Flint Hills do not make good cropland because the soil cover is thin and contains too much rock. Only the few existing level stretches and the valleys between the hills are used for growing crops of wheat and hay.

The central and western part of the study area is highly specialized and productive in the growing of wheat. The red silt loam of the gently rolling, reddish prairie is moderately fertile and produces good yields of wheat, except during drought periods. Precipitation in most years is ample for raising wheat and sorghum, but not for corn. As an additional source of income, most farmers in the area graze cattle in the river valleys and other places where the land is too rough and steep for crop farming.

To appraise the study area's future economic and population growth potential, comparisons are made of past growth trends in the study area economy with regional and national economic growth. Primary consideration is given to trends established over the past 20 years. The study area economic investigation included a survey of natural resources or products which might eventually be valuable as raw materials, an evaluation of personal income and employment growth, a look at the growth of industry (agriculture, services, manufacturing, and extraction of raw materials) and an analysis of population growth. Since historical records of personal income, employment, value of production and population are readily available, these dimensions are used to relate study area growth to national growth.

Income

The value of national output in goods and services (commonly termed gross national product (GNP)) is one of the most comprehensive measures of the national economy. A very useful and important method of relating regional growth with national growth would be a comparison of trends in regional output with national output. Regional product values which are greatly affected by government expenditures, are not available for the entire study area. Another important method of relating the economic situation in a region with the Nation is a comparison of effective buying power or disposable personal income.

Over the past 20 years, disposable personal income (that portion of income available for purchases of goods and services after Federal, State, and local taxes) has accounted for about 70 percent of GNP. Per capita disposable personal income trends for the study area, the adjoining States of Oklahoma and Kansas, and the Nation are shown in table VI-1. As shown by the table, per capita disposable income in the study area was about equal to the national average in 1940 and has held that position since. Investigation of personal income trends since 1940 indicates that both Kansas and Oklahoma are experiencing personal income growth in excess of the national rate. As indicated by these trends, per capita disposable personal income throughout the general region encompassing the study area may be expected to equal or exceed the national level in future years.

Table VI-1

Per Capita Disposable Personal Income for the Study Area, Kansas, Oklahoma, and the U.S. 1940, 1950, and 1960
(Constant 1960 Dollars)

	1940	1950	1960
Study Area	1,150	1,604	1,879
Kansas	952	1,501	1,805
Oklahoma	855	1,277	1,661
United States	1,185	1,624	1,997

Source: Sales Management 17/

Employment

Total labor force in the study area increased 50 percent between 1940 and 1960, from 162,000 to 243,000. This compares to increases of 29, 22, and 3 percent for the Nation, Kansas, and Oklahoma, respectively. See table VI-2.

As shown in table VI-2, some marked changes have occurred in the industrial mix of study area labor force over the past 20 years. Similar changes in employment patterns are occurring throughout the States of Oklahoma and Kansas; however, employment variations in the 10-county study area more closely parallel national trends. The most significant changes occurring in the employment pattern are shifts from employment in agriculture to employment in manufacturing and from resource-oriented manufacturing to nonresource-oriented manufacturing.

Between 1940 and 1960, agricultural employment in the study area dropped 54 percent from 29,600 to 13,400, or from 18.2 percent of the labor force to 5.5 percent. This closely parallels the national trend in agricultural employment which dropped 49 percent over the period, or from 16.2 percent of the Nation's labor force in 1940 to 6.4 percent by 1960. Similar declines in agricultural employment were experienced throughout the States of Oklahoma and Kansas although overall losses in the States as a whole were not as severe as in the study area. In contrast to these losses in agricultural employment, the percent of the labor force in the study area employed in manufacturing increased 230 percent from 18,100 to 59,800 between 1940 and 1960. The position of manufacturing employment relative to all other study area employment was greatly improved increasing from 11.2 percent of the labor force in 1940 to 24.6 percent in 1960. Growth in manufacturing employment in the study area appears striking when compared with national manufacturing growth. The Nation gained 64 percent in manufacturing employment

Table VI-2

Labor Force Distribution in the Study Area, Oklahoma, Kansas and the United States, 1940, 1950, 1960

Number

	Study Area			Oklahoma			Kansas			United States		
	1940	1950	1960	1940	1950	1960	1940	1950	1960	1940	1950	1960
Total Labor Force	162,292	199,752	243,107	729,382	783,123	821,936	666,015	725,509	813,591	52,705,082	59,303,720	68,144,079
Agriculture, Forestry, and Fisheries	29,592	23,979	13,489	218,795	155,018	73,858	183,945	162,879	104,486	8,559,134	7,033,591	4,349,884
Mining	5,966	5,686	6,634	35,009	39,969	35,129	15,211	14,756	14,503	918,853	930,968	654,006
Manufacturing	18,133	38,096	59,843	50,951	75,125	104,134	52,941	88,922	130,031	10,670,087	14,685,482	17,513,086
Resource Oriented	13,313	17,847	19,490	38,710	51,899	57,648	37,661	48,970	54,685	6,127,696	7,223,034	8,092,841
Nonresource Oriented	4,820	20,249	40,353	12,241	23,226	46,486	15,280	39,952	75,346	4,542,391	7,462,178	9,420,245
Total Extractive and Manufacturing	53,691	67,761	79,966	304,755	270,112	213,121	252,097	266,557	249,020	20,148,074	22,650,041	22,516,976
Service	88,012	126,433	153,039	348,784	483,399	572,827	327,929	441,064	534,857	24,922,241	33,799,368	42,122,276
Unemployed	20,589	5,558	10,102	145,843	29,612	35,988	85,989	17,888	29,714	7,634,767	2,854,311	3,504,827

Percent Change*

	Study Area	Oklahoma	Kansas	United States
	1940-1960	1940-1960	1940-1960	1940-1960
Total Labor Force	49.8	2.8	22.2	29.3
Agriculture, Forestry, and Fisheries	-54.4	-66.2	-43.2	-49.2
Mining	11.2	0.3	- 4.7	-28.8
Manufacturing	230.0	104.4	145.6	64.1
Resource Oriented	46.4	48.9	5.2	32.1
Nonresource Oriented	737.2	279.8	393.1	107.4
Total Extractive and Manufacturing	48.9	-30.1	- 1.2	11.8
Service	73.9	64.2	63.1	69.0
Unemployed	-50.9	-75.3	-65.4	-54.1

* Increase or decrease in labor force component

Source: Bureau of the Census 18 19/

between 1940 and 1960. A manufacturing growth rate higher than the Nation's is also occurring throughout the States of Kansas and Oklahoma. Gains in manufacturing employment of 146 percent (53,000 to 130,000) and 104 percent (51,000 to 104,100) were shown by Kansas and Oklahoma, respectively, during the period.

The trend toward nonresource-oriented manufacturing is another important change indicated in the industrial mix of the study area. In 1940, only 27 percent of the manufacturing labor force was engaged in nonresource-oriented manufacturing. By 1960, this industry group accounted for 68 percent of all manufacturing in the study area.

Extractive Inudstries

Agriculture

The Kaw study area contains about 10 percent of the total number of farms and acres of cropland harvested in Kansas and Oklahoma. Cash grain, livestock, and dairy products are the hard core of the agricultural economy in this area. As shown by table VI-3, a general decline in the number of farms and acres of cropland harvested is occurring in the area. This is in line with the national trend toward fewer and larger farms with increased productivity. Between the years 1944 and 1959, the total number of farms in Kansas and Oklahoma decreased by 37 percent, the same as experienced by the Nation. The drop in the number of study area farms was slightly less at 33 percent.

For the same period, Kansas and Oklahoma experienced a 23 percent drop in the total acres of cropland harvested, while the Nation and the study area experienced declines of 3 and 14 percent, respectively. The decreases, however, have been accompanied by increases in the total value of farm products sold. As shown by table VI-3, total farm production in the study area increased 58 percent between 1944 and 1959, compared to increases of 55 percent for the Nation and 24 percent for the combined Oklahoma and Kansas production.

As indicated by these trends, the study area is keeping pace with national growth in agriculture and is providing an increasing portion of the farm products sold in Kansas and Oklahoma.

Mineral Industries

Mineral extraction is an important part of the study area economy. The value of minerals produced in 1960 amounted to $175 million. Principal mining activities currently in progress include the recovery of petroleum, natural gas, natural gas liquids, and the extraction of sand, gravel, and stone. Other activities include the production of salt from well brines. As shown by table VI-4, mineral production, though experiencing slight fluctuations, showed an

Table VI-3

Summary of Agricultural Statistics for the Study Area
Oklahoma, Kansas, and the U.S.--1944, 1949, 1954, and 1959

Year	Region	Number of Farms (1,000's)	Acres of Cropland Harvested (millions)	Value of Farm Products Sold (Million Constant 1960 Dollars)		
				Crops	Livestock & Livestock Products	Total
1944	Study Area	24.0	2.8	34.5	58.1	92.6
	Oklahoma	164.8	14.1	221.6	216.6	438.2
	Kansas	67.7	12.8	204.0	191.6	395.6
	U.S.	5,967.0	403.0	8,424.1	11,113.2	19,537.3
1949	Study Area	21.0	2.5	43.4	57.9	101.3
	Oklahoma	142.2	11.9	251.2	199.9	451.1
	Kansas	63.5	12.0	195.0	198.8	393.8
	U.S.	5,648.0	409.0	9,804.1	11,221.6	21,025.7
1954	Study Area	19.0	2.3	54.7	51.8	106.5
	Oklahoma	119.0	10.2	198.4	194.3	392.7
	Kansas	58.5	11.9	212.5	193.1	405.6
	U.S.	5,087.0	399.0	11,276.8	12,438.9	23,715.7
1959	Study Area	16.0	2.4	68.4	77.2	145.6
	Oklahoma	94.7	9.0	250.6	324.7	575.3
	Kansas	51.1	11.5	277.2	333.5	610.7
	U.S.	3,704.0	391.0	13,600.4	16,786.0	30,386.4

Source: Bureau of the Census [20 21/]

overall gain of 42 percent in the study area between 1953 and 1960. Smaller gains of 10, 16, and 19 percent were experienced by Oklahoma, Kansas, and the United States, respectively.

Table VI-4

Value of Minerals Produced in the Study Area
Oklahoma, Kansas, and the U.S.--1953-1960
(Million Constant 1960 Dollars)

Year	Study Area	Oklahoma	Kansas	U.S.
1953	123.5	749.3	310.8	15,909.3
1954	138.4	726.7	350.6	15,741.6
1955	169.4	796.3	374.6	17,682.5
1956	180.8	822.7	382.2	18,867.0
1957	189.9	834.1	331.1	18,673.2
1958	179.4	823.2	337.6	17,718.6
1959	183.1	820.7	370.2	18,483.5
1960	175.0	827.2	371.8	18,994.8

Source: Bureau of Mines 22/

Manufacturing

The value added by manufacturing in the study area increased from $92 million in 1939 to $594 million in 1958. These data and comparable data for Oklahoma, Kansas, and the Nation appear in table VI-5. As shown in table VI-5, value added by manufacturing in recent years has grown more rapidly in the study area than in the Nation or in the region surrounding the study area. This growth, as indicated by the increasing value of production, is attributed to greater manufacturing diversification. This is pointed up by the presence of several large and generally unrelated industries in the area. In addition to large industries in meat-packing, oil refining, air conditioning equipment, and other transportation equipment, the study area contains one of the largest aircraft manufacturing centers in the Nation. In 1954, approximately 10 percent of all U. S. employment in aircraft manufacturing was engaged at one of the three large aircraft companies in the study area. 23/ Study area production of private planes in 1954 represented over one-half of the U. S. production in this category. In addition, the area contains one of the Nation's largest military aircraft production centers. Total employment for all three plants and associated industries amounted to over 40,000 in 1954. 23/

While comparable figures are not available for 1960, this represents about 16 percent of the study area's 1960 labor force. A large flour milling industry in the area has contributed to the development of major shopping and service centers for a portion of the winter wheat belt in Kansas and Oklahoma. As indicated in table VI-2, manufacturing in the study area presently accounts for a much larger part of the labor force than in the total of either Kansas or Oklahoma.

The percentage of the total labor force in manufacturing in the area was almost the same as that in the Nation in 1960. The manufacturing labor force distribution (table VI-6), however, shows considerable disparity between the study area and the Nation as a whole among different manufacturing categories. As shown, study area employment is much higher in fabricated metals, machinery, transportation, petroleum refining and related products (grouped under other nondurables), while employment in textiles and apparel and furniture, lumber and wood products is considerably below the national average.

Table VI-5

Value Added by Manufacturing in the Study Area
Oklahoma, Kansas, and the Nation
1939, 1947, 1954, and 1958
(Million Constant 1960 Dollars)

	1939	1947	1954	1958
Study Area	91.6	211.1	479.7	594.0
Oklahoma	208.0	412.5	606.2	646.5
Kansas	116.9	306.3	613.5	691.5
Nation	53,740.3	99,398.4	130,194.3	142,962.3

Source: Bureau of the Census 24/

Table VI-6

Distribution of Manufacturing Labor Force for the Nation and the Study Area--1960

Industry Group	Study Area (%)	United States (%)
Total Manufacturing	100.0	100.0
Resource-Oriented	32.5	37.5
Furniture, Lumber & Wood Products	0.7	7.0
Primary Metals	2.8	7.6
Food & Kindred Products	11.6	11.8
Chemical & Allied Products	1.5	5.2
Other Nondurables	16.0	5.8
Nonresource-Oriented	67.5	62.5
Fabricated Metals, Machinery, Transportation & Other Durable Goods	60.5	42.0
Textiles & Apparel	1.1	13.5
Printing & Publishing	5.9	7.0

Source: Bureau of the Census 19/

Population

The population of the study area increased 74 percent between 1920 and 1960. This amounts to an annual growth of 1.4 percent per year compared to a similar growth for the Nation over the period. Population trends are shown for the study area in table VI-7 by county and for principal towns within the counties As shown by these trends, population growth in the study area is attributed to a near three-fold increase in urban population since 1920. Most of this growth has occurred in the towns of Wichita, Enid, and Ponca City which had a combined population increase of 174 percent (116,000 in 1920 to 318,000 in 1960). For the same period, a 22 percent decline occurred in the study area rural population.

Future

General

Many factors are weighed in relation to the study area's past performance and future prospects to establish the region's potential for economic and population growth. The study area's economic and population growth in past years has closely paralled that of the Nation. In some parts of the economy, the study area and the general region encompassing the area are growing faster than the

Table VI-7

Population Trends of the Study Area 1920 - 1960

	Total Population				
	1920	1930	1940	1950	1960
KANSAS					
Sedgwick County	92,234	136,330	143,311	222,290	343,231
Wichita	72,217	111,110	114,966	168,279	254,698
Haysville	--	294	256	432	5,836
Derby	--	--	--	--	6,458
Sumner County	29,213	28,960	26,163	23,646	25,316
Wellington	7,048	7,405	7,246	7,747	8,809
Butler County	43,842	35,904	32,013	31,001	38,395
Augusta	4,219	4,033	3,821	4,483	6,434
El Dorado	10,995	10,311	10,045	11,037	12,523
Cowley County	35,155	40,903	38,139	36,905	37,861
Arkansas City	11,253	13,946	12,752	12,903	14,262
Winfield	7,933	9,398	9,506	10,264	11,117
OKLAHOMA					
Garfield County	37,500	45,588	45,484	52,820	52,975
Enid	16,576	26,399	28,081	36,017	38,859
Kay County	34,907	50,186	47,084	48,892	51,042
Ponca City	7,051	16,136	16,794	20,180	24,411
Blackwell	7,174	9,521	8,537	9,199	9,588
Tonkawa	1,448	3,311	3,197	3,643	3,415
Noble County	13,560	15,139	14,826	12,156	10,376
Perry	3,154	4,206	5,045	5,137	5,210
Payne County	30,180	36,905	36,051	46,430	44,231
Stillwater	4,701	7,016	10,097	20,238	23,965
Cushing	6,326	9,301	7,703	8,414	8,619
Pawnee County	19,126	19,882	17,395	13,616	10,884
Cleveland	2,717	5,521	5,252	2,861	2,519
Osage County	36,536	47,334	41,502	33,071	32,441
Pawhuska	6,414	5,931	5,443	5,331	5,414
Hominy	2,875	3,485	3,267	2,702	2,866
Tulsa	--	--	--	--	3,414
TOTAL	372,253	457,131	441,968	520,977	646,752
URBAN*	178,536	247,030	251,752	359,779	495,459
RURAL	193,717	210,101	190,216	161,198	151,293

* As defined by the Bureau of the Census.

Source: Bureau of the Census 25 26/

Nation and are expected to continue in this way for some time. In formulating future growth, it is therefore estimated that the study area will equal or exceed the national rate of growth both in population and in economic activities. Based on this criteria and in line with national economic growth projections 27/, total study area employment is expected to increase from 243,000 in 1960 to approximately 780,000 by the year 2020. The distribution of projected study area employment to the year 2020 is shown in table VI-8. Disposable personal income in the study area is expected to increase from $1,879 per capita in 1960 to about $6,000 per capita by the year 2020. This amounts to an increase of about 219 percent and compares to national projections made by the Ad Hoc Water Resources Council. 28/

Table VI-8

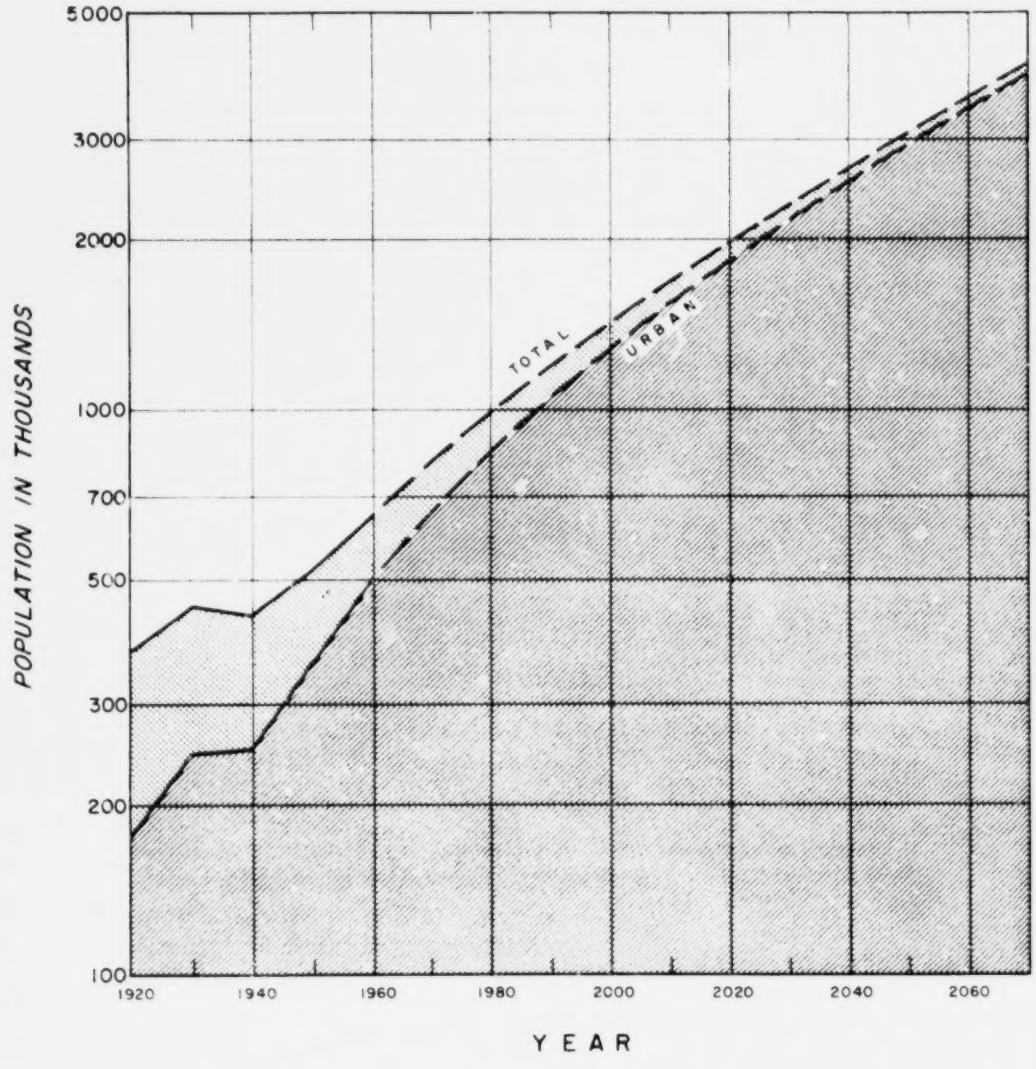
Distribution of
Projected Study Area Employment
(Year 2020)

Industry Group	Number	Percent
Total Labor Force	780,000	100.0
Agriculture	10,000	1.3
Mining	8,000	1.0
Manufacturing	195,000	25.0
Resource Oriented	55,000	7.0
Nonresource Oriented	140,000	18.0
Total Extractive & Manufacturing	213,000	27.3
Service	544,000	69.7
Unemployed	23,000	3.0

Industry

Agriculture presently plays a major role in the study area economy. Anticipations are that agricultural employment in the area will continue to decline for several years as it has in the past and stabilize in the neighborhood of 10,000 employees. Agricultural production on the other hand is expected to show significant gains in crop and livestock categories with accompanying increases in dairy production.

In view of the important position held by the study area in the production of both military and commercial aircraft and the increasing demands of the space age, the study area is expected to continue as one of the leading air transportation manufacturing centers in the Nation.



WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR–ARKANSAS RIVER BASIN
KANSAS AND OKLAHOMA

POPULATION TRENDS & PROJECTIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

V-H A

FIGURE VI-1

The influence of petroleum and its derivatives on manufacturing growth in the study area is also expected to continue for many years. Although crude petroleum and natural gas reserves in and bordering the study area will eventually be depleted, it is expected that growth in the study area petroleum refining industries will continue for another 50-60 years to meet the Nation's growing need for fuels and petroleum products. As study area petroleum and natural gas raw materials become exhausted or insufficient to meet the expanding needs of industry, it is expected that new supplies will be obtained from other regions and brought in by the large network of pipelines now traversing the southwest. A major source of future supply exists in the oil shale of the Colorado River basin. 29/ It is anticipated that present study area capacity (336,000 barrels per day in 1960) will increase to approximately 1 million barrels per day by the year 2020 with little growth occurring after that time.

Based on findings in previous studies 30/, the study area appears favorably situated for growth of the rapidly expanding petrochemical industry. It is anticipated that the area will become an important supplier of these commodities in future years, particularly in the production of fertilizers. Projected 2020 production of petrochemicals in the study area is 6,400 tons per day.

Several industries in the study area including the above mentioned petroleum refining and petrochemical industries are potentially large users of industrial water. Because of this, special consideration is given to the growth potential of these industries. In addition to petroleum refining and petrochemical production, other large water-using industries expected to grow in the study area include natural gas processing, food and kindred production, and thermal power generation.

Population

Based on the study area's economic potential and position, the region appears capable of maintaining, in the scheme of national population growth, total populations of 1,980,000 and 4,000,000 for the years 2020 and 2070, respectively.

A summary of study area population projections is presented in table VI-9 and shown on figure VI-1.

Table VI-9

Population Projections for the Study Area
2020 and 2070

Year	Population		
	Urban	Rural	Total
2020	1,850,000	130,000	1,980,000
2070	3,875,000	125,000	4,000,000

VII. WATER REQUIREMENTS

Municipal Water Use

Municipal water uses include residential, public, commercial, and those industrial uses which are served by organized public water supply systems and are reflected in a per capita water use.

Included in per capita quantities are losses in the distribution systems and treatment plants. Present per capita water use in the study area is 106 gallons per capita per day (gpcd) with total municipal water use averaging about 60 mgd. 8/

Future municipal water requirements are calculated by multiplying the estimated 2020 per capita use by the projected study area population served by public water supply systems. It is anticipated that by the year 2020 per capita water use in the study area will increase to between 180-190 gallons per day. This is indicated from a study of water use trends in the Arkansas and Red River basins. 30/ The projected supply need in the study area by the year 2020 is 337 mgd.

Industrial Water Use

Industrial water requirements are those significant quantities of water required in the manufacture of goods and the processing of materials more appropriately measured in use per unit(s) of production. These demands for water supply are exerted by the principal water-using industries described in Senate Select Committee Print No. 8. 31/

Production of these industries is usually predicated upon markets of national rather than local extent. Within the study area such industries include: power generation, petroleum refining, gas processing, petrochemical production, and food and kindred production.

Total study area water use by these industries is expected to reach 302 mgd by the year 2020. This estimate is based on levels of production and unit water needs assumed in the Public Health Service study "Water Quality Conservation, Arkansas-Red River Basins," March 1964. Figures used in computing water requirements are shown by industry in table VII-1.

Rural Water Use

A small portion of the total water need in the study area is that of nonmunicipal water supply for purposes other than irrigation. Generally, this includes domestic water for that portion of the population not served by municipal water systems and water for the

maintenance of livestock. The 2020 requirements for rural water are estimated to be 18 mgd, based on a nonmunicipal per capita water use of 136 gallons per day (gpd).

2070 Water Requirements

The total average daily water requirement for both municipal and industrial purposes is expected to reach about 1,090 mgd in the study area by the year 2070.

Per capita municipal water requirements through the year 2070 are expected to remain at about the same level as projected for the year 2020. The projected 2070 population expected to be served by public water supply systems in the study area is 3,875,000. Application of this growth to projected per capita water use indicates a municipal water supply need in the study area of 705 mgd by the year 2070.

It is anticipated that increases in industrial water needs after the year 2020 will be offset to some extent by improved efficiencies in water use and more extensive use of air cooling. As indicated in Chapter V, growth in the petroleum industry (the major water-using industry in the study area) is expected to level off within the next 50-60 years. Should this happen, water requirements for the industry will probably decline for reasons mentioned above.

Per capita industrial water use in the year 2020 (as determined from projected population and industrial water requirements) will be on the order of 150 gpd.

Since industrial production was not projected beyond the year 2020 in this study, 2070 industrial water requirements are estimated based on an anticipated per capita industrial water use. Based on expected changes in industrial water use trends as mentioned above, a per capita industrial water use of 100 gpd is projected for this area by the year 2070.

Table VII-1

Projected 2020 Industrial Water Requirements
By Industry for the Study Area

Industry	2020 Production	Unit Water Use	Water Requirements (MGD) Misc. (Sanitary & Process)	Cooling Water	Total
Petroleum Refining	990 Thousand BBL/DAY	145 GAL/BBL	41	100	141
Natural Gas Processing	700 Million Cu-Ft/DAY	4 GAL/1000 cu-ft.	1	2	3
Petrochemical Production	6,400 Tons/Day	10,700 Gal/Ton	21	47	68
Thermal Power Generation	62.7 KWH/CAP/Day*	0.7 Gal/KWH		86	86
Food and Kindred Production	--	--	4		4
			67	235	302

*Kilowatt - hours per capita per day.

VIII. WATER QUALITY CONTROL

A major factor in providing adequate water resources for any sector of the country is the problem of waste disposal. Thorough water planning for an area must include not only adequate water supplies for municipal and industrial users, but must also insure that adequate assimilative flows exist in the streams which receive the treated waste of an area. Otherwise, as it has been found, municipal and industrial waste waters (even after a relatively high degree of treatment) may degrade the quality of a receiving stream to the point where fish and wildlife, recreation, water supply, and other uses of the stream will be impaired.

Congress emphasized the importance of water quality control as it applies to our Nation's water resources by the enactment of the Federal Water Pollution Control Act, Public Law 84-660, as amended by Public Law 87-88. Under the provisions of this act, consideration must be given to the inclusion of storage for regulation of streamflow to control water quality in any reservoir being planned by a Federal agency. Storage and release of this water are not to be provided as a substitute for adequate treatment of wastes at the source.

Good municipal waste treatment practice appears to be common in the study area. In 1962, approximately 49 mgd of municipal waste flows with an estimated population equivalent (PE)* of 130,000 were discharged to study area streams. Almost all of these wastes received secondary treatment prior to discharge. Principal sources of municipal waste discharge in the study area include the towns of Wichita, Arkansas City, and Eldorado, Kansas, and Enid, Ponca City, and Stillwater, Oklahoma. Industrial waste flows are largely associated with the oil, gas, and salt recovery operations.

Evaluation of future stream conditions and the subsequent need for water quality control in the study area is based on parameters of water quality which are currently available for use. To meet the objectives of this study, two broad parameters, dissolved oxygen content and dissolved solids, are used. Dissolved oxygen consumption is used as a measure of the organic waste load (those constituents which will decompose in the stream). It is one of the most meaningful measures of water quality for which predictive techniques can be applied. Dissolved oxygen is a significant factor in maintaining an environment for propagation of fish and other aquatic life.

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* The calculated population which would normally contribute the same amount of BOD per day.

Dissolved solids are employed to characterize the effects of stable pollutants (those constituents which are not utilized or reduced by the stream environment), such as chloride and sulfate salts. These constituents are generally not affected in the treatment of municipal wastes. Because of cathartic effects and taste and laxative properties, dissolved solids in excessive amounts are undesirable in waters used for public water supplies. By abatement of natural and manmade chloride pollution much can be done toward improving the mineral quality or dissolved solids content of study area streams. As indicated in earlier sections of the report, efforts are being made to substantially reduce mineral pollution in the study area. Full utilization of study area water resources may depend on the outcome of these activities.

In evaluating the need for water supply storage for water quality control purposes in the study area, expected amounts of future municipal and industrial waste return flows were estimated and the following criteria or conditions assumed:

1. Sufficient treatment will be provided to remove 90 percent of the BOD from treated municipal and industrial waste waters. The assumed level of BOD removal is based on the following considerations:

   a. As an outgrowth of extensive pollution abatement activities now underway and under consideration in the study area, high effluent standards can be expected of future waste treatment facilities in the area.

   b. The conveyance of sanitary sewage and storm drainage by separate collecting systems is now a common practice in the study area. Storm drainage and infiltration are not expected to significantly affect future treatment of municipal and industrial waste flows in the area.

   c. Modern waste treatment plants in the southwest are frequently reporting higher rates of BOD removal.

2. No dissolved solids removal will be achieved by treatment.

3. Uniform mixing of wastes and receiving waters will occur.

4. Minimum dissolved oxygen content of 4 mg/l will be needed in study area streams to prevent nuisance conditions from occurring and support fish life and encourage recreation and other uses of the streams.

Allowances for Streamflow

In determining the amount of water from storage required to preserve the quality of the stream, it is necessary to make allowances for natural flows that can be expected to occur in the stream in absence of the project. Estimated natural streamflows at the Kaw damsite are shown in Appendix B, tables B-1 and B-2 for the period April 1922 to April 1962. Flows shown in tables B-1 and B-2 have been modified to show different stages of upstream development and a prior water right in the vicinity of the reservoir.

Annual Draft-On-Storage Needed to Control Water Quality

An analysis of the procedure used in evaluating storage requirements for water quality control purposes is shown in Appendix B.

A summary of the storage requirements for control of water quality below Kaw Reservoir is given in table VIII-1.

Table VIII-1

Annual Draft on Storage Needed for Water Quality Control
Below Kaw Reservoir
(Acre-Feet)

Year and Condition	Percent of Time Water Quality is Protected		
	95%	90%	80%
2020			
Condition A a/	8,200	2,800	--
Condition B	6,200	1,700	--
2070			
Condition A a/	13,000	7,500	--
Condition B	12,000	5,000	--

a/ See Appendix B - based on stages of upstream development.

For purposes of this study, it is assumed that the draft-on-storage at the 95 percent protection level will be needed to assure adequate protection of water quality in the receiving stream and attain full utilization of the water resources of that portion of the Arkansas River within the study area.

Values of water quality control storage are, therefore, based on annual draft-on-storage of 8,200 acre-feet by the year 2020 and 13,000 acre-feet by the year 2070.

A schedule of minimum flows or releases (with the reservoir in place) needed to maintain water quality below Kaw Reservoir is shown in table B-3 of Appendix B.

Water Quality Control Needs in the Wichita Area

In the foregoing discussion estimated storage requirements necessary for maintaining satisfactory stream quality below Kaw Reservoir were given.

Recognition is also given to future needs for water quality control above the proposed reservoir site. Plans for maintaining adequate stream quality in the Walnut River are presented in a previous report by the Public Health Service. 32/

However, further consideration should be given to future water quality conditions in the reach of the Arkansas River between Wichita and Arkansas City. Based on projected BOD loadings in treated waste flows at Wichita, pollution conditions will exist in this reach of the river unless measures are taken to control water quality. Projected BOD loadings in treated waste flows at Wichita, Kansas, are estimated in the neighborhood of 50 tons per day by the year 2070. To adequately assimilate waste loads of this magnitude, expected low flows in the Arkansas River at Wichita would need to be increased by about 160,000 acre-feet per year.

In the absence of flow regulation and with BOD loadings of the magnitude indicated (2070), dissolved oxygen levels in the river between Wichita and Arkansas City would drop to near zero during low flow conditions. It is doubtful that regional water resources in the vicinity of Wichita, Kansas, (even if not used for other purposes) would be of sufficient magnitude to provide adequate flow regulation below Wichita. If nuisance conditions in the stream are to be avoided, and dissolved oxygen levels maintained which will support fish life, advanced waste treatment measures will probably be needed at Wichita eventually.

IX. WATER SUPPLY AND WATER QUALITY CONTROL PLAN

General

Plans for supplying the projected water supply needs shown in the previous section were developed using all available water resources in the study area. A summary of present study area municipal water supplies and estimated maximum potential yields is given in table IX-1.

Plans for supplying water to the study area are shown by area of need for the years 2020 and 2070 in table IX-2. Communities with sufficient water supplies to meet projected requirements are not shown. As shown by table IX-2, future needs for water supply storage in Kaw Reservoir are expected to occur in the areas of Wichita, Kansas, Ponca City, Oklahoma, and Stillwater, Oklahoma.

Alternatives

Wichita

Present and planned water supplies of the city of Wichita, including the newly constructed Cheney Reservoir on the North Fork of the Ninnescah River and planned expansion of well fields in the Equus Beds appear capable of meeting the areas projected municipal water needs until the year 1988. To meet expected increases in water needs after this time will require extensive development of regional resources and possibly transporting water from eastern Kansas or from areas outside the Arkansas River basin. Studies by the city of Wichita [6/] indicate that the most likely sources of water that could be developed outside of south-central Kansas would be streams in eastern Kansas where rainfall is higher and the topography would allow for construction of large reservoirs.

Because of high transmission costs (most likely reservoir sites would be on the Neosho River over a hundred miles from Wichita), this source of supply has not been too attractive.

The Kanopolis Reservoir on the Smoky Hill River in the Kansas River basin and Fall River Reservoir in the Verdigris River basin have both been considered as future water supply sources for the city of Wichita. However, most of the available storage in these reservoirs is now committed, and the possibility of diverting water to Wichita (over 70 miles in each instance) appears remote.

Potential water supply sources in south-central Kansas include: the Chikaskia River, South Fork of the Ninnescah River, Arkansas River, Walnut River, and Little Arkansas River. All of these sources have been investigated by the city of Wichita, but none have been developed to date, either because of low yields or generally undesirable water quality.

Table IX-1

Study Area Municipal Water Supplies

State Area Designation	Surface Water Source	Yield (mgd)	Ground Water Source	Yield (mgd)
Kansas				
Wichita & Vicinity	Cheney Reservoir	38.0	91 Wells	96.0
Eldorado & Augusta	Impoundments, Walnut River	2.5		
Wellington	Lake Wellington	3.0	24 Wells	2.0 a/
Arkansas City & Winfield			12 Wells	9.0 a/
Oklahoma				
Ponca City & Vicinity	Lake Ponca, Lake Blackwell, Chikaskia River	21.0	86 Wells	27.6
Enid	Canton Reservoir, North Canadian River	20.0	84 Wells	29.0
Stillwater & Vicinity	Lake Carl Blackwell, Cushing Lake, Lake Perry, Other Small Imp.	13.1	9 Wells	3.0
Pawhuska	Pawhuska Lake	3.0		
	TOTAL	100.6		166.5

a/ Estimate

Source: State-Federal Municipal Water Facilities Inventory 8/, and City Water Departments and City Engineers

Table IX-2

Assumed Plans for Meeting Projected Study Area Water Requirements
(All quantities in mgd, except as noted)

State / Area Designations	Supplemental Water Requirements 2020 M&I Water Supply	2020 Water Quality Control (ac.-ft./yr.)	2070 M&I Water Supply	2070 Water Quality Control (ac.-ft./yr.)	Potential Sources With Construction of the Proposed Multipurpose Kaw Reservoir: Source	Yield	Without the Proposed Project: Source	Yield
Kansas								
Wichita & Vicinity	144 [a]	22,000	440 [a]	162,000	Arkansas River [b]	107 [c]		
					Kaw Reservoir	41 [d]	Single Purpose Project at the Kaw site	41
					Murdock Reservoir	58		
					Corbin Reservoir	38		
					Little Arkansas River	15		
					Other Surface Water Development	--- [e]		
Eldorado, Augusta, Arkansas City, Winfield	[f]			[f]	Walnut River Basin			
Wellington			5		Corbin Reservoir			
Oklahoma								
Ponca City & Vicinity	35 [g]	8,000	79 [g]	13,000	Arkansas	73 [h]		
					Kaw Reservoir	79	Single Purpose Project at the Kaw site	79
Stillwater & Vicinity	26		47		Kaw Reservoir	47	Single Purpose Project at the Kaw site	47

[a] Excludes industrial cooling water.
[b] Source of industrial cooling water, 2020 use - 53 mgd, 2070 use - 66 mgd.
[c] Based on 50-year drought cycle.
[d] Storage in Kaw Reservoir could be used to satisfy part of the projected water needs at Wichita.
[e] To meet the long-range water supply needs at Wichita, water may have to be imported from other river basins.
[f] These areas can be more efficiently supplied by proposed impoundments in the Walnut River basin. A water supply plan is presented in the Public Health Service study entitled "Storage for Municipal and Industrial Water Supply and Water Quality Control, Walnut River Basin," April 1963.
[g] Excludes water for thermal power generation.
[h] A water right for streamflow up to 73 mgd is held for thermal power generation at Ponca City.

The Bureau of Reclamation has proposed construction of the Murdock Reservoir on the South Fork of the Ninnescah River, approximately 34 miles from Wichita, as a source of future water supply for the city. The project would provide a dependable yield of approximately 58 mgd but because of objectional chloride content would probably be used as a secondary supply source and for industrial and recreational purposes. 6/

Also under consideration by the Bureau of Reclamation is a reservoir on the Chikaskia River near Corbin, Kansas. This reservoir would provide a dependable yield of 38 mgd. 33/ Water in the Chikaskia River is of good chemical quality. In view of the relatively small yield and distance from Wichita (approximately 50 miles) the project may not become too attractive unless a central reservoir-pipeline system using water from both Kaw and Corbin Reservoirs could be developed.

The Little Arkansas River has generally been rejected as a water supply by Wichita because of lack of a reservoir site and poor quality during periods of low flow. Studies by the Wichita Water Department indicate that the river in the vicinity of Wichita could yield about 30 mgd of good quality water six months of the year without construction of a reservoir. With abatement of pollution, it is expected this yield could be increased. 6/

In conjunction with a study of the feasibility to control flooding in the vicinity of Halstead (approximately 20 miles upstream from Wichita) the Corps of Engineers is currently investigating the possibility of a multiple-purpose reservoir on the Little Arkansas River at this site. 34/ These studies have not progressed to the point where a firm water supply yield can be established. However, preliminary studies indicate a water supply yield between 4 and 8.5 mgd may be possible.

The Walnut River does not appear to be a likely source of water supply for the city of Wichita, primarily because of poor quality in tributaries near the city and the fact that almost all available resources in the stream will eventually be needed to satisfy local needs. The city of Wichita has given little consideration to the river as a supply source because of pollution.

The Arkansas River has not been developed as a water supply source largely because of wide fluctuations in hardness and chloride content. Some consideration has been given to diverting flood flows at Wichita into off-stream storage areas. Storage of surface water directly on the river at this point is impractical because of flat topography in the river valley. Consideration has also been given to use of the river in recharging the Equus Beds or in creating an

underground reservoir by installing well systems in underlying gravel deposits along the river bank near Wichita. With abatement of both natural and manmade pollution entering the stream, the river would probably be the most likely source of future water supply development. With or without pollution abatement, the river provides a convenient source of industrial cooling water and should be used more extensively in future years.

For purposes of this study, it is assumed that continuing efforts in the abatement of natural and manmade salt pollution will make possible mineral concentrations in Kaw Reservoir equal to or better than levels shown on figure A-3, if the reservoir is constructed. This would significantly enhance its value for municipal water supply storage in the reservoir. Based on studies of future water needs in the vicinity of Kaw Reservoir and information presently available, only 126 mgd of the 167 mgd water supply yield of the reservoir will be needed to satisfy the needs of Oklahoma communities to the year 2070. This leaves approximately 41 mgd which could be used to meet the future water needs of Wichita. By use of a common pipeline (about 40 miles in length) and lateral lines, 17 miles to Corbin and 20 miles to Kaw, Wichita could obtain 79 mgd from a combined Corbin and Kaw Reservoir system. By mixing water from the two reservoirs, mineral concentrations within limits recommended for drinking water supplies could be obtained most of the time due to the superior mineral quality of Corbin Reservoir.

Since a combined Kaw and Corbin Reservoir water supply system would provide both a good quality water supply and a potential yield of 79 mgd, it is expected that this supply will be the most likely source to satisfy long-range water needs of Wichita, either with or without the proposed Kaw Reservoir project. However, since an estimated 15 mgd of water (annual average) can be diverted from the Little Arkansas River into Wichita's water system with little effort, it is expected that this supply will be utilized before additional development. On this basis water from Kaw Reservoir is expected to be needed by the year 1995.

Ponca City and Vicinity

Existing ground and surface water supplies in the area of Ponca City and Blackwell appear capable of meeting the area's projected water needs for the next 25 to 30 years. Over half of the above supply is obtained from well fields in the alluvium of the Arkansas River and is of poor mineral quality. (See table V-3.) To achieve satisfactory water quality in finished domestic supplies, ground water is now blended with higher quality water from Lake Ponca.

Because of the short distance and ease of transmission, the most likely alternative to supply the area's future water needs would be a single-purpose reservoir at the proposed project site. Water

diverted from the reservoir to supply Ponca City would flow by gravity into the town's water supply system less than 8 miles away.

Stillwater and Vicinity

Combined water supplies of the towns of Stillwater, Cushing, and Perry appear sufficient to meet expected increases in regional water use for the next 20 to 30 years. Use of the Kaw Reservoir as a future water supply source has been given strong consideration by the communities of Stillwater and Perry. Preliminary investigations have already been made of the feasibility of supplying the two towns by a common pipeline. 35/ With abatement of natural mineral pollution, the Cimarron River would provide a more convenient source of supply assuming a satisfactory reservoir site could be found. However, in view of the nature and extent of this pollution (table V-3), it is doubtful that even with recommended pollution abatement measures 36/ mineral quality in this stream could be improved to levels comparable to those expected in Kaw Reservoir.

In view of the above considerations, it is anticipated that in the absence of the proposed Kaw Reservoir project a single-purpose reservoir at the same site would be the most likely source to satisfy the area's future water needs.

X. BENEFITS

Municipal and Industrial Water Supply Benefits

Method of Evaluation

Currently, due to wide fluctuations in chemical quality, waters that would be stored in the proposed Kaw Reservoir remain largely unused for municipal and industrial water supply purposes. Assuming continued improvement in chemical quality due to pollution abatement activities upstream from the project site, the reservoir can supply much of the future water requirements in north-central Oklahoma and south-central Kansas.

Senate Document No. 97 (87th Congress, 2nd Session) states that when measuring benefits of storage in Federal reservoirs for municipal and industrial water supply purposes ". . . the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in absence of the project." In supplying future municipal and industrial water needs in the study area, a single-purpose reservoir at the site of the proposed project is considered the most likely alternative.

Costs and Water Supply Benefits

The first cost and the annual operation, maintenance, and replacement costs for this reservoir are based on evaluations and agreements reached by the Public Health Service and the U. S. Army Engineer District, Tulsa, Oklahoma.

For purposes of comparison, alternate costs were converted to equivalent annual costs using an amortization period of 25 years and a non-Federal interest rate of 4 percent. On this basis, the 167 mgd of storage in Kaw Reservoir for municipal and industrial water supply purposes will have an annual value of $1,753,000. The 1970 (assumed base year) or present worth value of the above annual value is $1,105,000.

Water Quality Control Storage Benefits

Benefits attributable to storage for streamflow regulation for water quality control may be tangible, i.e., have a measurable dollar value or intangible with no measurable dollar value. Such benefits are defined as the net contribution to public health, safety, economy, and effectiveness in use and enjoyment of water for all purposes which are subject to detriment or betterment by virtue of change in water quality.

Representing intangible benefits, water quality control management by the proposed Kaw Reservoir will provide recreational

opportunities in the Arkansas River for a distance of approximately 75 miles from the dam to Keystone Reservoir located on the main stem of the Arkansas near Tulsa, Oklahoma. Assured water quality will provide favorable conditions for recreation for those living in and near the Oklahoma portion of the study area. It is estimated that the urban population in the Oklahoma portion of the study area, plus that of the city of Tulsa*, will be in the order of 2.8 million by the year 2070. All would be within an easy drive of the river and able to enjoy the opportunities it would offer. Since portions of the Arkansas River below Keystone Reservoir (near the city of Tulsa) will become highly urbanized it is not unlikely that residents of Tulsa will be attracted to the more rural atmosphere of the stream reach in question. In addition to the recreational benefits, riparian property owners will enjoy improved aesthetics of the stream stemming from clean surface waters and a satisfactory public health water environment.

Supplemental flow regulation releases recommended for water quality control below Kaw Reservoir will protect sport fishing (estimated currently in the neighborhood of 1,600 man-days per year) in this reach of the river.** It is further anticipated that these releases will improve sport fishing on the order of 1,350 man-days per year.** By providing these releases during the summer months when water quality control needs are the most severe, sufficient flow will be maintained in the stream to permit higher species of game fish to live in the area.

Construction of the Kaw Reservoir will provide more uniform quality downstream from the reservoir. If abatement is made of mineral pollution above the reservoir as mentioned in Chapter III, and natural salt pollution entering from the Salt Fork tributary below the reservoir, the river could become attractive as a source of industrial water supply.

If required storage for streamflow regulation is not provided as recommended, benefits described above will not be realized. Without streamflow regulation, it is estimated that the projected waste loads of three tons of BOD per day will result in a dissolved oxygen concentration in the river at times approaching zero.

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*Population projections were made for the city of Tulsa in the Public Health Service report, "Water Resources Study, Keystone Reservoir, Arkansas River Basin, Oklahoma," March 1964 (Working Draft).

**Findings of the Fish and Wildlife Service.

This means that most of the fish life in the stream will leave the area in favor of waters that more nearly provide the environment they require. If the dissolved oxygen concentration drops near zero the stream will become the source of various odors and paint-blackening fumes. Recreation will suffer and property values will decline in areas contiguous to the stream.

Senate Document No. 97 permits the following method of measuring benefits of storage in Federal reservoirs for water quality control:

> "In situations where no adequate means can be devised to evaluate directly the economic effects of water quality improvement, the cost of achieving the same results by the most likely alternative may be used as an approximation of value."

This alternative cost method was used to determine the value of storage in Kaw Reservoir for water quality control purposes. The computed value represents the minimum value of benefits such as those listed above. Two single-purpose reservoirs, Silverdale located on Silver Creek, and Beaver located on Beaver Creek, are the most likely alternative in this case. The two reservoirs would provide a combined draft-on-storage of 13,000 acre-feet annually, all of which is expected to be needed to maintain satisfactory stream quality below Ponca City by the year 2070.

Since two reservoirs would be used to supply required flow regulation needs, it is assumed that the larger reservoir, Silverdale, which will provide an annual draft-on-storage of 7,300 acre-feet per year, would be constructed first. This supply would be needed by the year 1990. Beaver Reservoir, which will provide an annual draft-on-storage of 5,700 acre-feet per year, would be needed by the year 2000.

The first costs and the annual operation and maintenance costs for the two reservoirs are also based on evaluations and agreements reached by the Public Health Service and the Tulsa District Office of the Corps of Engineers. Reservoir costs were converted to equivalent annual costs using an amortization period of 100 years and a Federal interest rate of 3 1/8 percent. On this basis, the annual value of water quality control storage in Kaw Reservoir would be $503,000. The 1970 present worth of this value is $238,000.

Calculations used in computing value of storage for municipal, industrial, and water quality control purposes are shown in Appendix C.

Since water quality control management by the proposed Kaw Reservoir will assure water quality in the Arkansas River for a distance of approximately 75 miles and thereby provide recreational opportunities for an estimated potential population of about 3

million and enhance use of the stream by future industry locating within a 10-county area, benefits to water quality control storage in the project are considered widespread in scope.

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APPENDIX - F

APPENDIX A

Analysis of Mineral Quality - Kaw Reservoir

Since waters that would normally flow into Kaw Reservoir are of variable mineral quality and are undesirable for water supply purposes during certain times of the year, studies were made to determine the effect storage in the reservoir will have toward stabilizing the quality of flows by mixing dilute flood flows with highly concentrated low flows.

An analysis of mineral quality was made using weighted monthly average mineral concentrations measured at Arkansas City and Winfield, Kansas. Records of water quality at Arkansas City are available for January - May 1907, October 1951 - September 1958, and July 1960 - September 1962. 12-14 16/ Quality records at Winfield are available from July 1960 to September 1962. 12-14 16/

For each of the points of record, correlations of the dissolved solids quality characteristic against stream discharge was investigated. The computed correlation coefficient was better than 0.9 for both points indicating a strong relationship between dissolved solids and streamflow. Curves showing these relationships are shown on figure A-1. For comparison with stream quality at Winfield, a similar curve is also shown of the dissolved solids - discharge relationship at Arkansas City between July 1960 and September 1962. As shown by the latter curve, dissolved solids loads per unit of discharge at Arkansas City between July 1960 and September 1962 (a wet period) were significantly lower than indicated by the long-term record. Consequently, mineral loadings at Winfield are expected to be higher over a longer period of time than indicated by available records, and more comparable in quality to Arkansas City flows. On the basis of this assumption and in view of the fact that a major portion (approximately 70 percent) of the flow into Kaw Reservoir is contributed by the Arkansas River above Arkansas City, the long-term quality records at Arkansas City were used to describe quality of inflows into Kaw Reservoir. (See figure A-2.)

Using concentrations shown on figure A-2, a dissolved solids routing was made for the proposed reservoir based on monthly inflows and an operation schedule provided by the Corps of Engineers. Monthly inflows based on assumed conditions of upstream development are included in Appendix B. Inflows occuring under condition "A" are lower and were therefore used in the analysis.

With the computed monthly dissolved solids concentrations, a dissolved solids duration curve for Kaw Reservoir was constructed and is shown (solid line) on figure A-3.

An investigation was then made of the correlation of chlorides and sulfates with dissolved solids at Arkansas City. These minerals, it was found, are a major contributing factor to the dissolved solids load at Arkansas City, and show a strong relationship at either high or low levels. Using equations from the constructed curves of best fit (chlorides vs. dissolved solids, and sulfates vs. dissolved solids) to compute plotting positions, chloride and sulfate duration curves were constructed as shown (solid line) on figure A-3.

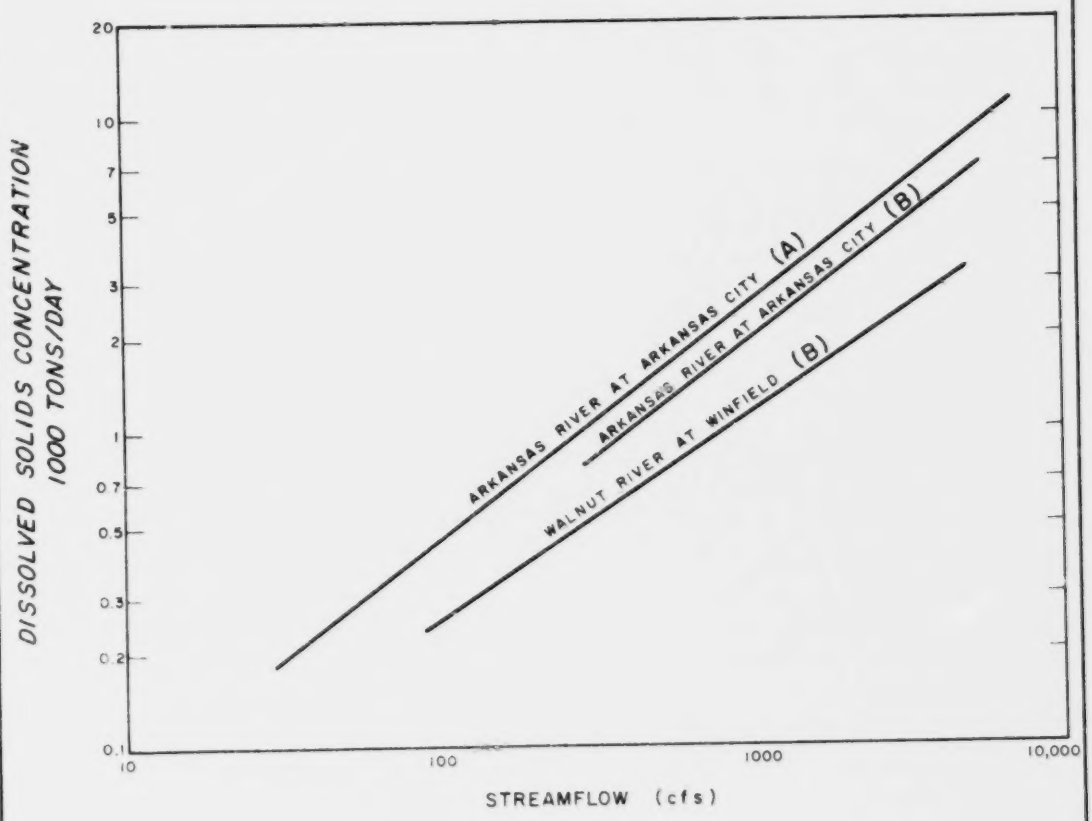
As shown by the solid lines on figure A-3, dissolved solids concentration in the reservoir will exceed 500 mg/l approximately 90 percent of the time, and surpass 1,000 mg/l about 15 percent of the time. Chlorides will exceed 250 mg/l about 40 percent of the time, with an upper limit of approximately 525 mg/l. Public Health Service Drinking Water Standards-1962 5/ gives upper limits of 500 mg/l and 250 mg/l, respectively, for dissolved solids and chlorides in finished waters.

It is apparent that the dilution effect of reservoir storage is not enough, in itself, to make the water suitable for municipal use all the time. Adverse quality has been, and will continue to be, a major factor limiting the use of Arkansas River water, unless steps are taken to reduce pollution. Dissolved mineral concentrations in Kaw Reservoir would be substantially improved if the pollution abatement objectives of the Arkansas-Red River basins water quality conservation project are achieved. 36/ The project proposed control of both natural and manmade chloride pollution in the two basins where feasible. At the present time, an estimated 1,200 tons of chloride (Cl^-) pass the Kaw damsite daily. These loads are attributed to both natural and manmade upstream salt pollution. Manmade salt pollution is attributed to oil and gas, and salt recovery industries in Kansas. 36/

Natural salt brines enter the Arkansas River at several locations upstream from the Kaw site, either by seepage from underground salt springs or by runoff from exposed salt deposits. This form of salt pollution, however, does not appear as significant as manmade pollution in the form of oilfield brines and water from salt works.

Kansas and Oklahoma each have active programs for control of manmade pollution. Although much is being done through present pollution abatement programs in these areas, an additional reduction of about 1,000 tons of salt (NaCl) per day upstream from the Kaw site has been recommended. 36/

Based on an average salt load reduction of 1,000 tons per day, dissolved solids and chloride concentrations in the reservoir would be reduced to approximately those levels shown by the dashed lines on figure A-3. Under these conditions, dissolved solids concentrations would range from about 280 mg/l to 950 mg/l, and exceed 500 mg/l about



PERIOD OF RECORD

(A) JAN 1907 – MAY 1907
OCT 1951 – SEP 1958
JUL 1960 – SEP 1962

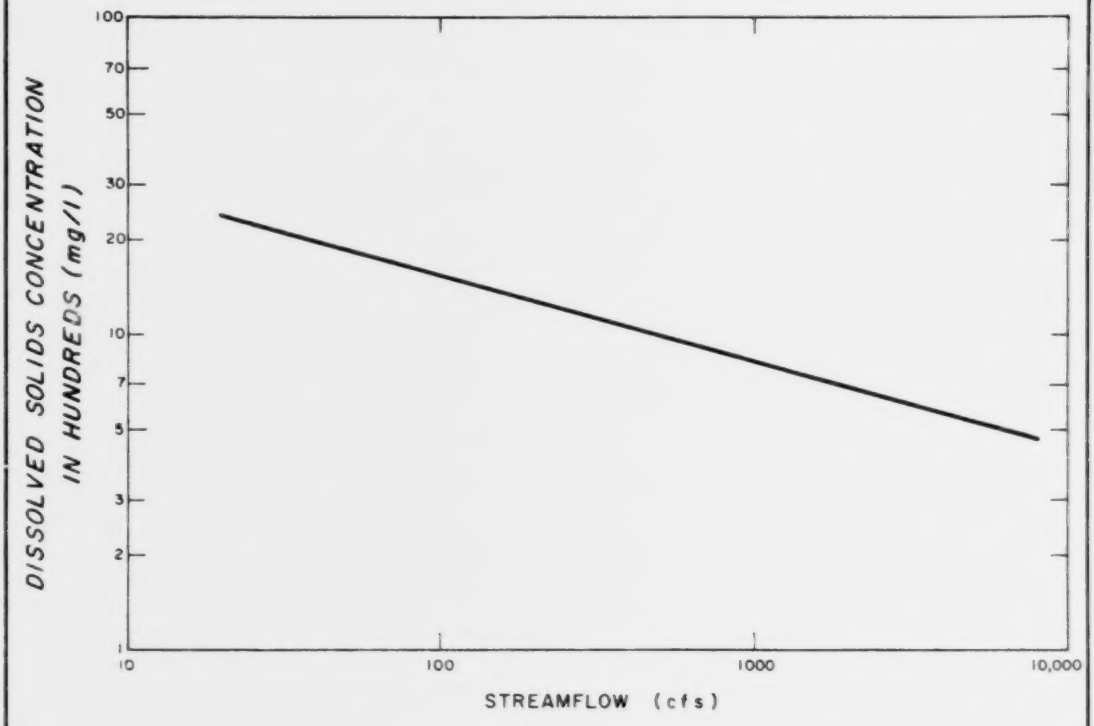
(B) JUL 1960 – SEP 1962

WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR–ARKANSAS RIV BASIN–KAN. & OKLA.

DISSOLVED SOLIDS–
STREAM DISCHARGE RELATIONSHIP
(ARKANSAS CITY & WINFIELD KANSAS)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE A–1



PERIOD OF RECORD:

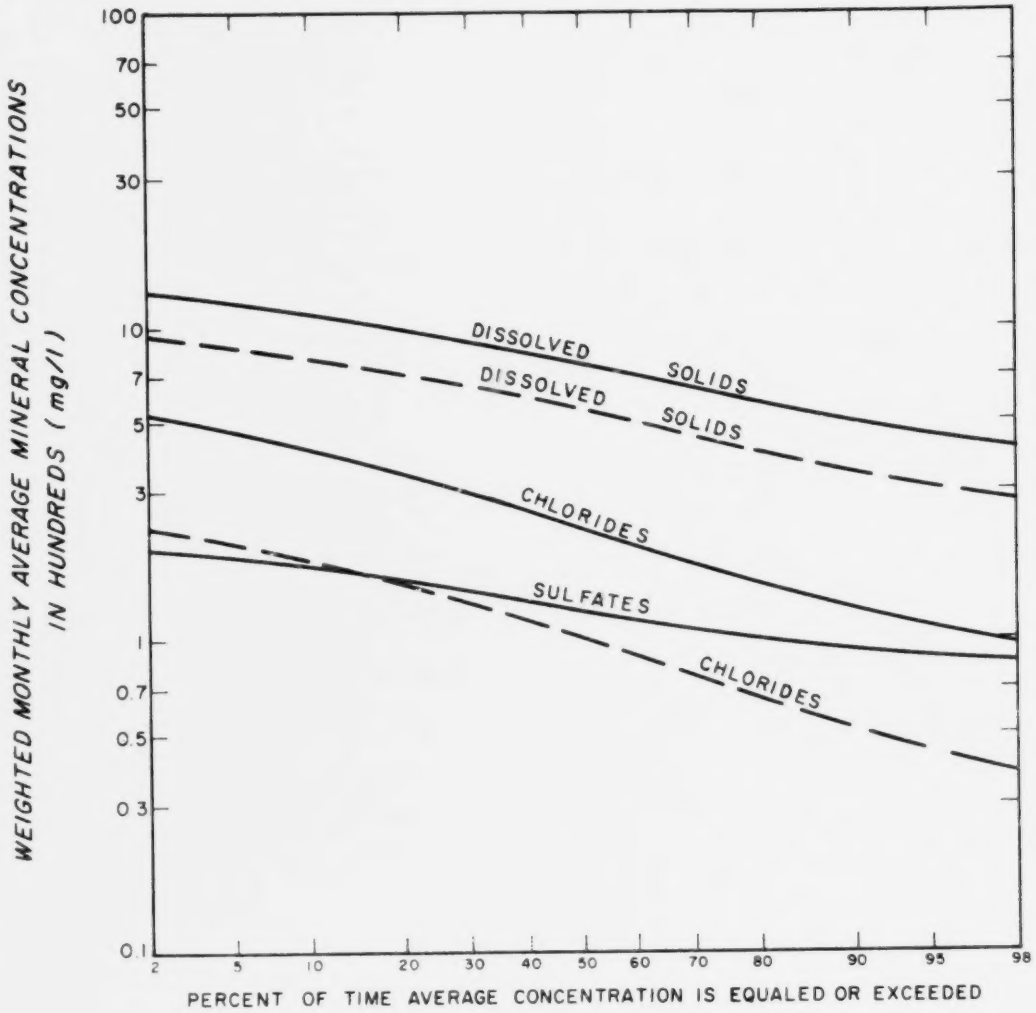
JAN 1907 – MAY 1907
OCT 1951 – SEP 1958
JUL 1960 – SEP 1962

WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR–ARKANSAS RIV. BASIN – KAN & OKLA

DISSOLVED SOLIDS CONCENTRATION VS. STREAMFLOW
(ARKANSAS CITY)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE A – 2



NOTE

PERIOD OF ROUTING — 1922–1962
STORAGE UTILIZED
WATER QUALITY RECORDS USED – ARKANSAS CITY
Jan 1907 – May 1907
Oct 1951 – Sep 1958
Jul 1960 – Sep 1962

SOLID LINES – WITHOUT RECOMMENDED UPSTREAM SALT POLLUTION ABATEMENT
DASHED LINES – WITH RECOMMENDED SALT POLLUTION ABATEMENT

WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR–ARKANSAS RIV. BASIN – KAN & OKLA

KAW RESERVOIR DISSOLVED MINERAL CONCENTRATION DURATION CURVES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE A – 3

55 percent of the time. Chloride levels would be greatly improved with concentrations ranging from 35 to 240 mg/l.

Although dissolved solids concentrations will still exceed upper limits (500 mg/l) of the Public Health Service Drinking Water Standards a good portion of the time even after recommended reductions in upstream mineral pollution, much of this amount can be attributed to hardness. Measured hardness in ground water samples taken from the alluvial aquifer at Ponca City has exceeded 700 mg/l. 37/

APPENDIX B

Water Quality Control Needs--Method of Analysis

In evaluating the need for streamflow regulation for water quality control in the study area, estimates of natural streamflow must be made for points where water quality problems are expected to occur.

Based on projected waste return flows to the Arkansas River in the study area, significant water quality control needs for which storage in Kaw Reservoir can be provided will be largely centered in the area of Ponca City, Oklahoma. Provision of adequate streamflow at this point in the river to protect water quality will assure satisfactory water quality downstream from this point.

Since Ponca City is located immediately below the Kaw Damsite, estimated natural discharges at the damsite are used to evaluate flow regulation needs at Ponca City.

Tables B-1 and B-2 show estimated streamflow at the Kaw Damsite from April 1922 to April 1962 as modified by different stages of upstream development, and a prior water right in the vicinity of the reservoir. 38/

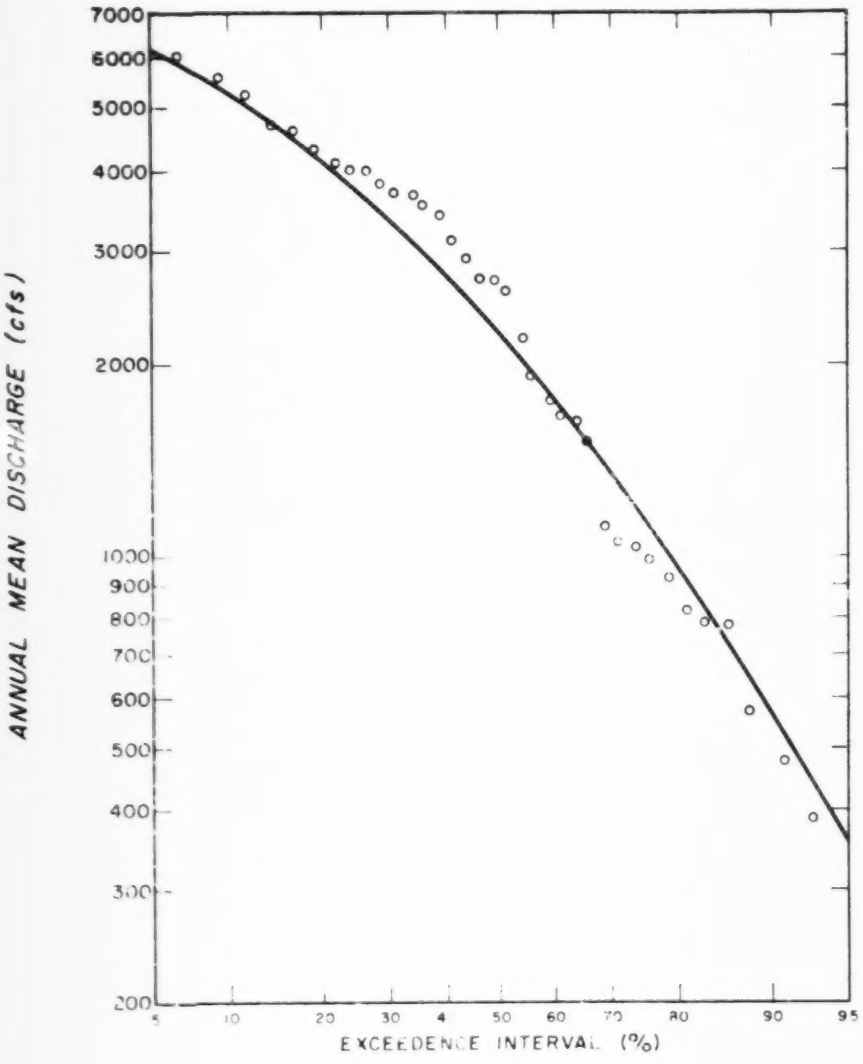
Monthly streamflows shown in table B-1 under condition "A" represent streamflows for the period of record as modified by ultimate development of Cheney Reservoir, now completed, (figure III-1) and reduction of streamflow up to 113 cfs (when inflow equals or exceeds this amount) for a prior water right near the damsite.

Flows shown in table B-2 under condition "B" represent the above conditions with further modifications for ultimate development of proposed impoundments 39/ in the Walnut River basin.

A 60 percent return of the municipal and industrial water supply yield of upstream impoundments is assumed under both conditions. The discharge frequency curves shown on figures B-1 and B-2 were constructed using data from the two tables.

Minimum monthly flows which will be needed in the Arkansas River below Kaw Reservoir for water quality control are shown in table B-3 for the years 2020 and 2070. These flows represent minimum dilution needs (during periods of no streamflow) for assimilation of waste discharges to the Arkansas River below Kaw Reservoir.

Hydrographs of projected minimum monthly streamflow requirements shown in table B-3 were compared to hydrographs of the estimated natural flows shown in tables B-1 and B-2 for each year of record.



NOTE

BASED ON NATURAL FLOWS AT ARKANSAS CITY AND WINFIELD, KANSAS AS MODIFIED BY:

(1) ULTIMATE DEVELOPMENT OF CHENEY RESERVOIR ASSUMING 60% RETURN FLOW FROM THE RESERVOIRS WATER SUPPLY YIELD

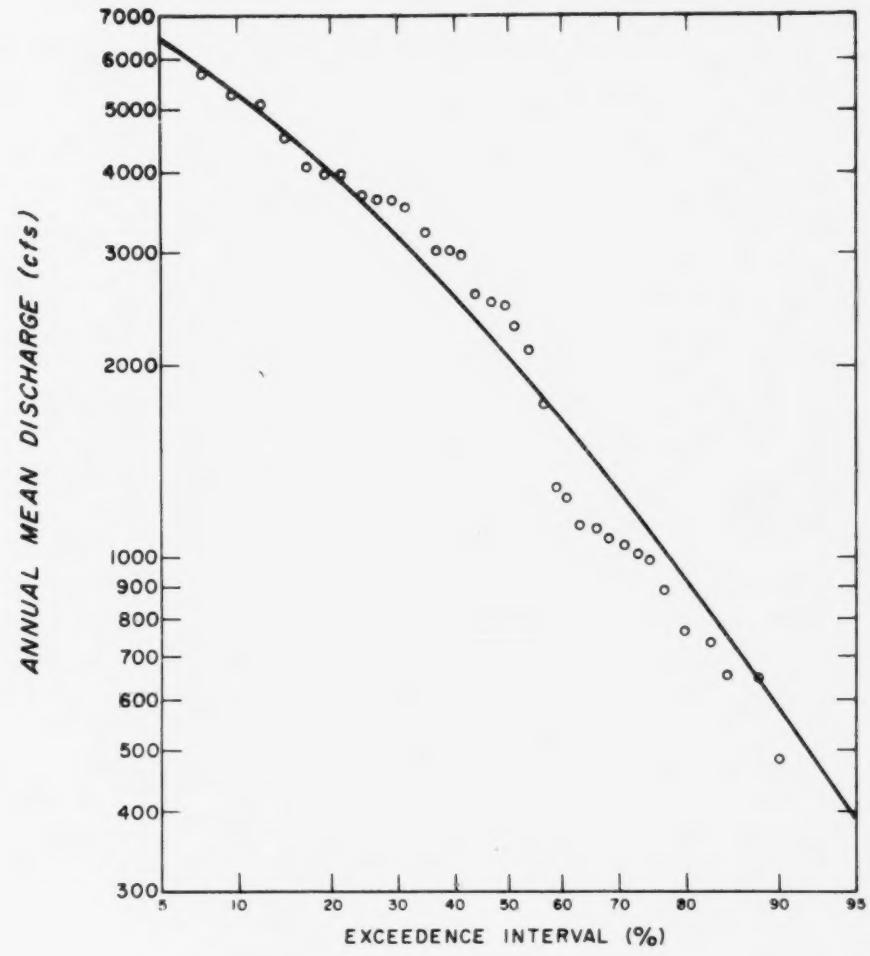
(2) DEDUCTION OF INFLOWS UP TO 113 cfs FOR PRIOR WATER RIGHT WHEN INFLOW EQUALS OR EXCEEDS THIS AMOUNT

WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR--ARKANSAS RIV. BASIN--KAN. & OKLA.

FREQUENCY OF ANNUAL MEAN DISCHARGE-KAW DAMSITE
CONDITION A

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE B-1



NOTE

BASED ON NATURAL FLOWS AT ARKANSAS CITY AND WINFIELD, KANSAS AS MODIFIED BY:

(1) ULTIMATE DEVELOPMENT OF CHENEY, ELDORADO, TOWANDA & DOUGLASS RESERVOIRS ASSUMING 60% RETURN FLOW FROM THE WATER SUPPLY YIELDS OF THESE RESERVOIRS

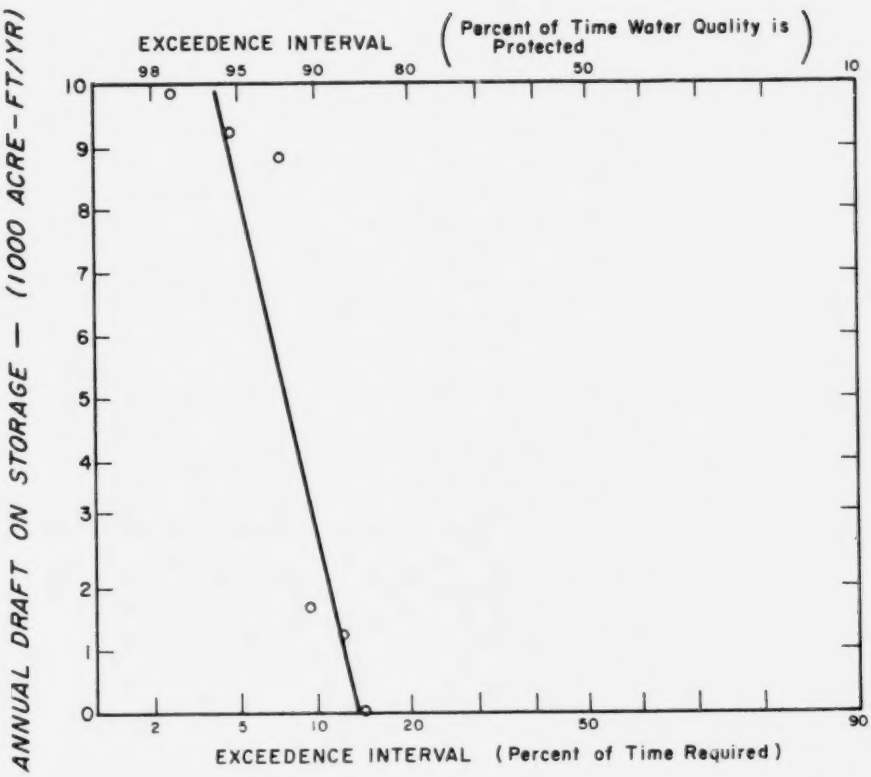
(2) DEDUCTION OF INFLOWS UP TO 113 cfs FOR PRIOR WATER RIGHT WHEN INFLOW EQUALS OR EXCEEDS THIS AMOUNT

WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR–ARKANSAS RIV. BASIN–KAN. & OKLA.

FREQUENCY OF ANNUAL MEAN DISCHARGE–KAW DAMSITE
CONDITION B

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE B–2

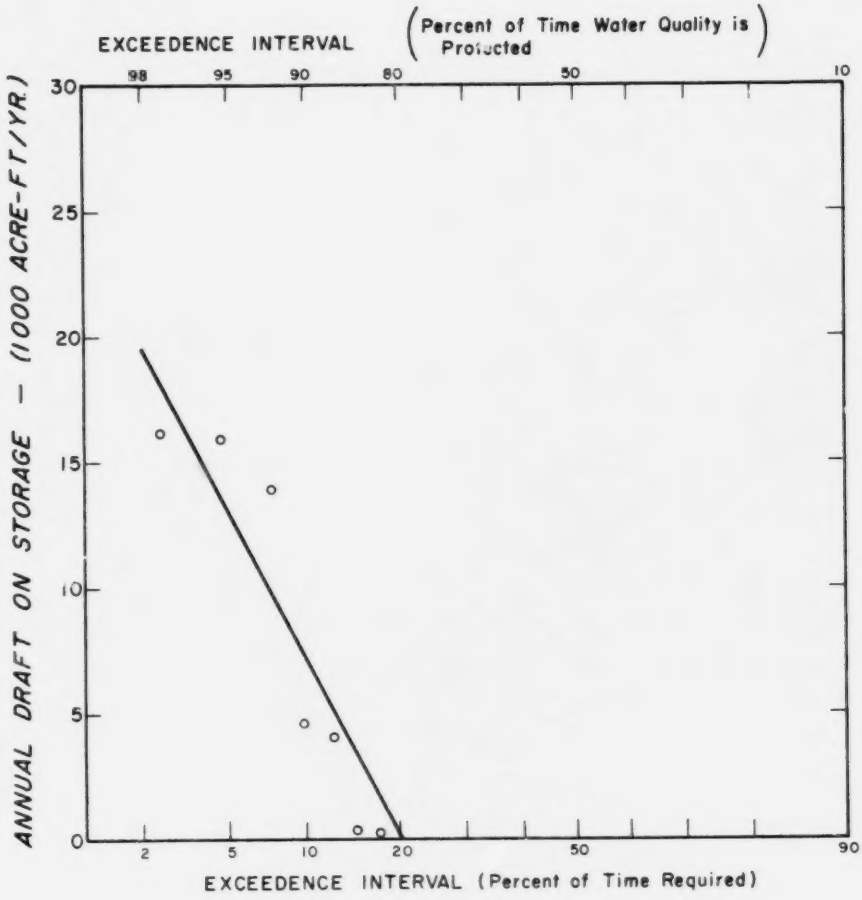


WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR – ARKANSAS RIV. BASIN – KAN. & OKLA.

SUPPLEMENTAL WATER QUALITY CONTROL REQUIREMENTS – ARKANSAS RIVER BELOW KAW RESERVOIR (YR 2020) CONDITION "A"

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE B-3

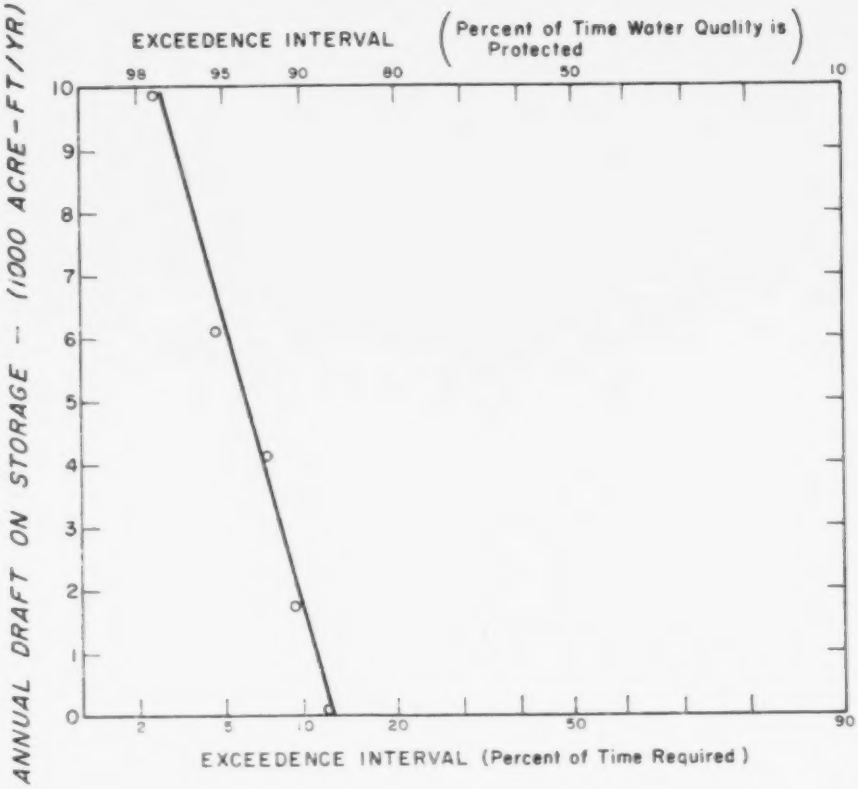


WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR–ARKANSAS RIV. BASIN – KAN. & OKLA.

SUPPLEMENTAL WATER QUALITY CONTROL REQUIREMENTS–ARKANSAS RIVER BELOW KAW RESERVOIR (YR 2070) CONDITION "A"

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE B–4

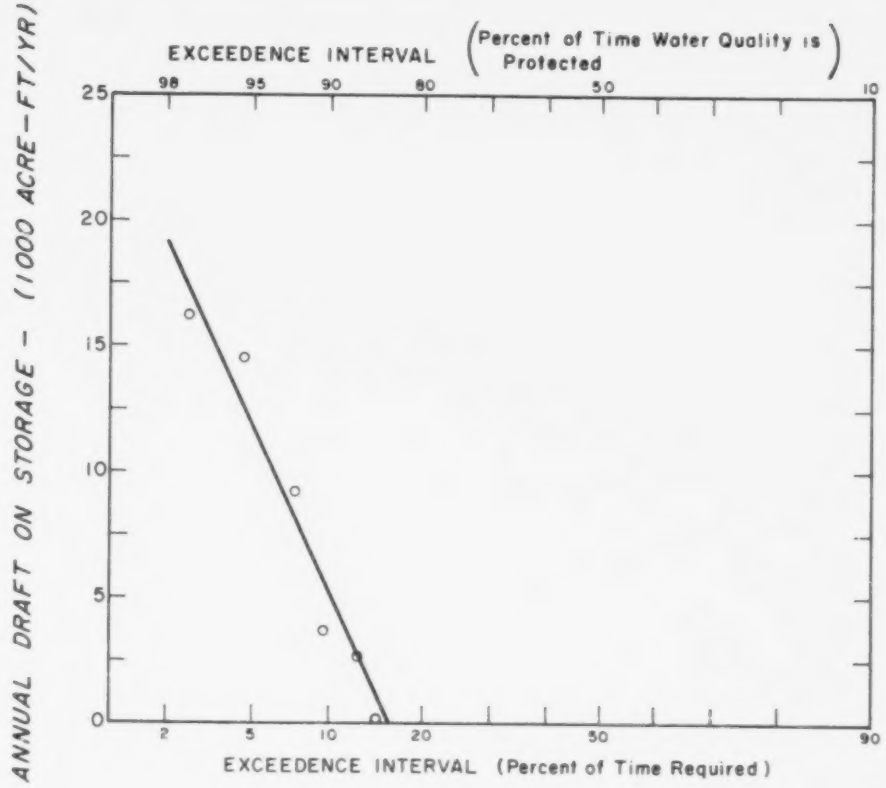


WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR–ARKANSAS RIV. BASIN – KAN. & OKLA.

SUPPLEMENTAL WATER QUALITY CONTROL REQUIREMENTS – ARKANSAS RIVER BELOW KAW RESERVOIR (YR 2020) CONDITION "B"

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE B-5



WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR – ARKANSAS RIV. BASIN – KAN. & OKLA.

SUPPLEMENTAL WATER QUALITY CONTROL REQUIREMENTS – ARKANSAS RIVER BELOW KAW RESERVOIR (YR 2070) CONDITION "B"

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE B-6

The sum of the monthly deficits has been determined for each year and is shown in table B-4 as supplemental water quality control requirements, or annual draft-on-storage.

Probability levels shown in figures B-3 through B-6 are based on supplemental water quality control requirements given in table B-4 and the computed plotting positions in table B-5. These figures indicate the estimated draft-on-storage needed at various levels of water quality protection. Further examination of the curves shows a greater need for st rage occurring under condition "A". A summary of estimated storage requirements under both conditions "A" and "B" is given in table B-6.

Table 5

Modified Monthly Discharge, Key Damsite a/
(Condition - A) b/
(acre-feet)

Climatic Year c/	April	May	June	July	August	September	October	November	December	January	February	March
1923	448,891	457,688	91,240	579,659	47,909	17,416	12,185	115,470	21,751	5,409	1,545	5,766
1924	9,808	178,498	1,511,440	133,383	145,390	145,390	248,409	155,298	83,929	54,535	113,471	187,124
1925	201,680	296,308	63,601	45,353	57,122	12,482	17,596	16,940	16,822	19,140	33,108	23,280
1926	53,793	51,653	57,895	4,696	40,479	22,786	14,919	30,730	17,119	24,727	29,720	28,125
1927	67,526	35,545	17,596	9,748	30,552	188,722	669,651	75,984	48,028	38,755	39,052	20,08
1928	958,946	127,796	293,218	86,129	796,972	240,554	176,358	59,143	46,423	30,762	59,618	116,918
1929	162,212	108,300	1,029,441	235,620	72,101	19,377	15,633	443,482	172,138	216,659	62,590	10,527
1930	297,557	313,903	463,394	407,223	96,709	26,332	6,538	37,507	49,514	26,807	64,433	39,706
1931	23,895	266,529	122,090	12,898	10,818	91,062	36,615	59,916	59,559	43,332	38,458	22,448
1932	82,503	83,454	206,376	23,300	7,727	12,364	-0-	183,491	48,265	45,174	50,583	45,056
1933	22,290	29,007	179,687	138,436	16,762	8,975	3,626	5,350	8,084	14,325	14,384	20,150
1934	15,157	63,125	29,542	12,898	242,456	183,967	24,549	16,227	14,860	16,346	10,699	18,383
1935	59,202	42,678	20,388	2,615	-0-	5,944	26,549	64,433	11,175	16,584	14,662	13,157
1936	21,398	708,109	677,854	213,746	25,262	22,884	29,898	79,531	30,552	23,182	10,818	20,566
1937	12,661	37,804	86,723	14,384	27,580	12,780	121,317	18,961	19,615	46,720	98,314	103,675
1938	62,297	136,236	254,998	235,798	66,513	72,933	18,605	13,374	17,119	14,860	15,989	37,906
1939	56,944	650,987	374,710	91,716	122,090	69,664	23,122	52,961	26,451	24,489	20,863	21,540
1940	62,828	30,671	169,998	110,737	88,922	16,465	6,598	6,717	8,381	3,982	15,276	21,302
1941	91,181	205,544	91,122	59,083	19,140	115,611	13,850	33,405	37,566	63,898	84,048	87,269
1942	191,397	125,181	461,076	223,554	77,450	142,180	360,444	269,498	130,352	91,954	147,887	117,493
1943	552,792	578,173	720,472	301,480	164,114	382,021	345,881	117,691	237,344	181,946	143,548	93,380
1944	88,090	550,058	548,750	134,453	43,807	35,486	34,475	31,622	29,126	35,783	41,370	424,104
1945	1,606,842	689,445	585,900	192,467	159,061	149,076	213,984	71,031	456,758	111,093	102,593	302,609
1946	1,152,244	581,026	162,093	193,121	69,961	292,742	558,023	77,807	59,559	130,530	92,608	164,708
1947	91,775	67,227	46,244	23,776	9,213	352,955	86,366	104,496	64,017	45,056	42,797	189,079
1948	938,201	469,219	422,856	226,466	55,933	22,766	16,940	19,615	47,433	28,175	34,832	280,141
1949	85,83	65,860	386,776	1,293,117	393,255	106,100	59,618	81,849	64,195	396,919	842,800	342,856
1950	291,256	687,305	700,441	228,309	117,453	158,170	115,670	64,136	59,797	73,884	70,971	55,876
1951	42,678	82,859	176,121	532,939	1,128,409	310,217	180,400	84,583	78,223	73,527	100,156	104,912
1952	147,827	1,370,092	1,125,556	167,086	273,186	736,759	222,900	246,260	142,953	146,936	120,544	294,106
1953	272,414	195,676	148,719	44,639	37,566	18,367	12,245	22,112	32,811	40,835	42,737	58,905
1954	76,618	132,254	42,797	41,727	53,080	13,493	8,916	23,479	28,293	19,972	27,877	27,402
1955	22,647	78,580	47,671	9,273	654	-0-	3,448	4,161	5,409	10,461	15,811	15,813
1956	19,912	127,439	172,138	60,272	15,454	14,384	252,026	26,803	20,269	20,745	25,619	27,233
1957	21,993	15,336	16,168	17,178	1,189	-0-	-0-	1,843	2,437	2,199	6,301	12,435
1958	190,505	891,838	1,175,129	549,761	90,765	160,488	83,394	108,419	61,402	62,115	66,870	449,359
1959	339,997	245,309	146,044	792,097	344,455	309,861	112,104	72,794	58,059	63,482	83,751	116,562
1960	113,649	252,620	109,667	530,740	135,345	108,240	982,543	132,470	111,509	129,758	212,736	497,869
1961	580,848	345,525	249,648	153,415	341,839	141,289	145,450	132,962	87,080	58,667	96,828	179,359
1962	203,463	1,070,336	232,767	372,094	589,169	530,026	446,276	680,059	200,313	192,764	295,238	125,15

a/ Source: Corps of Engineers
b/ Modified to show ultimate development of Cheney Reservoir (Figure III-1) and reduction of streamflow up to 113 cfs for [illegible] water right near the damsite. A 60 percent return of the municipal and industrial yield of Cheney is assumed.
c/ April 1st to March 31.

Table B-2

Modified Monthly Discharge - Kaw Damsite [a]
(Condition B) [b]
(acre-feet)

Climatic [c] Year	April	May	June	July	August	September	October	November	December	January	February	March
1923	449,584	459,947	89,979	574,888	43,101	18,014	7,186	104,976	31,232	3,046	7,079	141,545
1924	6,907	163,990	1,525,615	134,965	147,351	146,661	244,968	151,360	83,875	5,842	2,046	4,373
1925	203,146	295,957	59,193	42,464	51,655	13,177	16,942	17,395	17,520	53,583	112,216	180,439
1926	49,079	47,937	25,896	6,627	42,940	23,386	16,330	29,263	18,644	14,801	32,928	21,904
1927	62,923	31,036	10,875	9,221	28,038	149,463	640,095	77,028	45,599	25,105	31,012	29,216
1928	96,465	128,195	296,225	81,472	817,827	241,839	174,056	56,283	45,105	35,022	35,260	68,414
1929	163,859	106,428	1,035,739	222,040	68,247	19,864	15,491	439,096	170,956	49,091	57,925	113,293
1930	294,226	311,924	460,381	402,283	90,811	26,414	7,264	36,890	50,192	215,752	59,383	103,423
1931	23,766	238,585	117,368	13,855	12,112	79,312	37,086	51,506	57,973	27,544	62,268	39,424
1932	75,570	78,366	180,957	21,476	8,233	7,906	-0-	161,158	45,540	43,588	38,478	21,143
1933	31,821	27,092	170,457	132,645	15,557	9,798	5,158	6,829	8,959	43,916	47,885	41,798
1934	16,717	60,341	31,214	13,536	216,912	180,957	26,086	18,025	16,574	15,789	15,842	21,458
1935	52,916	11,077	16,836	4,497	1,904	2,802	20,976	48,829	9,233	18,109	12,481	20,375
1936	20,387	647,739	674,230	209,851	25,486	24,206	24,998	64,475	28,335	15,682	14,784	15,015
1937	13,778	35,379	88,337	64,820	29,888	13,338	88,854	21,012	19,358	22,303	11,565	21,208
1938	51,679	118,807	244,337	233,361	61,995	67,242	19,882	14,486	17,978	34,867	91,252	52,321
1939	49,050	634,193	371,307	89,330	114,839	68,295	24,581	53,654	27,538	16,098	16,913	33,689
1940	61,632	31,000	166,762	110,877	79,431	18,454	8,662	8,697	10,191	25,777	21,946	27,235
1941	61,536	188,857	86,855	59,948	20,143	112,769	15,557	29,644	35,510	5,717	16,788	24,766
1942	177,054	120,455	443,290	217,495	74,624	141,562	361,360	267,330	128,290	52,643	77,807	55,522
1943	552,662	573,728	738,812	298,182	159,635	383,603	344,953	114,471	237,329	89,723	146,750	113,679
1944	84,030	547,701	272,844	127,612	42,167	36,009	34,617	32,452	28,793	179,083	140,533	89,080
1945	154,960	687,020	283,226	188,762	156,346	145,762	208,881	69,895	459,174	35,527	41,625	397,738
1946	115,470	278,931	158,559	190,695	67,509	295,124	554,375	74,713	57,723	109,230	99,991	301,376
1947	87,516	63,732	44,118	25,129	9,965	25,745	85,963	102,055	63,755	129,545	90,062	132,353
1948	931,762	467,883	418,292	223,784	56,819	24,611	18,864	21,303	47,235	45,415	43,648	162,925
1949	85,029	66,962	344,614	1,288,708	385,840	105,975	60,710	79,723	64,279	29,471	34,463	270,513
1950	287,527	684,117	694,022	222,719	115,327	149,962	111,746	63,452	58,919	379,064	841,076	339,206
1951	41,542	80,924	158,261	519,645	1,125,200	303,821	178,119	83,827	77,718	71,519	70,496	55,135
1952	137,868	1,370,947	1,126,717	1,727,952	267,610	735,213	218,751	243,540	139,903	73,083	93,994	100,717
1953	266,735	191,177	144,662	44,136	37,943	20,078	14,057	23,106	21,405	144,156	117,594	290,252
1954	70,615	96,713	37,681	41,518	54,636	15,509	10,815	24,772	29,596	41,708	43,642	54,362
1955	23,915	79,086	49,079	11,107	3,105	2,112	5,110	6,116	7,418	21,595	29,210	28,335
1956	21,357	124,132	166,655	62,173	17,698	14,646	239,513	28,775	21,642	12,422	16,473	17,175
1957	22,047	14,986	15,398	16,479	1,112	-0-	-0-	1,820	2,409	21,922	26,556	22,814
1958	170,558	788,219	1,109,721	536,189	90,710	153,359	82,084	100,972	59,413	2,195	5,711	12,356
1959	333,715	239,453	139,564	786,868	342,109	301,126	110,776	69,710	66,962	66,727	63,583	475,331
1960	106,374	239,941	105,172	496,230	130,224	104,774	982,977	128,266	109,711	62,518	81,686	84,654
1961	278,032	361,235	242,636	147,833	336,785	136,363	140,771	128,665	5,112	127,707	210,565	493,618
1962	198,250	1,070,053	222,445	371,907	288,122	529,669	443,403	680,131	198,340	56,938	92,787	177,245

a/ Source: Corps of Engineers
b/ Modified to show ultimate development of Cheney Reservoir (Figure III-1)and proposed impoundments 39/ in the Walnut Basin and reduction of streamflow up to 113 cfs for a prior water right near the damsite. A 60 percent return of the municipal and industrial yield of Cheney and proposed impoundments on the Walnut River is assumed.
c/ April 1st to March 31.

Table B-3

Minimum Monthly Streamflow
Required for Water Quality Control [a]
Below Kaw Reservoir

	Year 2020 Mean		Year 2070 Mean	
	cfs	acre-feet	cfs	acre-feet
January	0	0		0
February	0	0		0
March	7.1	422	11.0	654
April	28.5	1,695	44.6	2,653
May	57.0	3,391	89.3	5,312
June	78.4	4,664	122.8	7,305
July	99.8	5,937	156.2	9,292
August	99.8	5,937	156.2	9,292
September	57.0	3,391	89.3	5,312
October	28.5	1,695	44.6	2,653
November	7.1	422	11.0	654
December	0	0	0	0
TOTAL				
Acre-feet/year		27,554		43,127
mgd		25		39

[a] Minimum discharges (or releases with the reservoir in place) needed to maintain water quality in the Arkansas River at Ponca City. Since no appreciable drainage area lies between the damsite and the point of need, dilution from runoff in the intervening area is negligible. (This table is not to be taken as a recommended operating schedule but used only as an example of minimum anticipated dilution needs.)

Table B-4

Supplemental Water Quality Control Requirements
Arkansas River Below Kaw Reservoir
(Needed by Years 2020 and 2070) a/
(acre-feet)

Climatic Year b/	Condition "A" (2020)	Condition "A" (2070)	Condition "B" (2020)	Condition "B" (2070)
1923	--	--	--	--
1924	--	--	--	--
1925	--	--	--	--
1926	1,241	4,596	--	2,665
1927	--	--	--	--
1928	--	--	--	--
1929	--	--	--	--
1930	--	--	--	--
1931	--	--	--	--
1932	1,695	4,216	1,695	3,712
1933	--	--	--	--
1934	--	--	--	--
1935	9,259	15,969	6,062	14,693
1936	--	--	--	--
1937	--	--	--	--
1938	--	--	--	--
1939	--	--	--	--
1940	--	--	--	--
1941	--	--	--	--
1942	--	--	--	--
1943	--	--	--	--
1944	--	--	--	--
1945	--	--	--	--
1946	--	--	--	--
1947	--	79	--	--
1948	--	--	--	--
1949	--	--	--	--
1950	--	--	--	--
1951	--	--	--	--
1952	--	--	--	--
1953	--	--	--	--
1954	--	--	--	--
1955	8,674	13,950	4,111	9,387
1956	--	--	--	--
1957	9,834	16,068	9,911	16,145
1958	--	--	--	--
1959	--	--	--	--
1960	--	--	--	--
1961	--	--	--	--
1962	--	--	--	--

a/ Annual draft-on-storage needed for water quality control by the years 2020 and 2070 based on the low monthly discharges shown (underlined) in tables B-1 and B-2.

b/ April through March.

Table B-5

Plotting Positions in Percent

	Condition "A"			Condition "B"	
	Storage Requirement (acre-feet)		n / N + 1 a/	Storage Requirement (acre-feet)	
	2020	2070	(Percent)	2020	2070
1.	9,834	16,068	2.44	9,911	16,145
2.	9,259	15,969	4.88	6,062	14,693
3.	8,674	13,950	7.31	4,111	9,387
4.	1,695	4,596	9.16	1,695	3,712
5.	1,241	4,216	12.20	0	2,665
6.	0	79	14.63	0	0
7.	0	0	17.07	0	0
8.	0	0	19.51	0	0
9.	0	0	21.95	0	0
10.	0	0	24.39	0	0
11.	0	0	26.83	0	0
12.	0	0	29.27	0	0
13.	0	0	31.71	0	0
14.	0	0	34.15	0	0
15.	0	0	36.59	0	0
16.	0	0	39.02	0	0
17.	0	0	41.46	0	0
18.	0	0	43.90	0	0
19.	0	0	46.34	0	0
20.	0	0	48.78	0	0
21.	0	0	51.22	0	0
22.	0	0	53.66	0	0
23.	0	0	56.09	0	0
24.	0	0	58.54	0	0
25.	0	0	60.98	0	0
26.	0	0	63.41	0	0
27.	0	0	65.85	0	0
28.	0	0	68.29	0	0
29.	0	0	70.73	0	0
30.	0	0	73.17	0	0
31.	0	0	75.61	0	0
32.	0	0	78.05	0	0
33.	0	0	80.49	0	0
34.	0	0	82.93	0	0
35.	0	0	85.37	0	0
36.	0	0	88.80	0	0
37.	0	0	90.24	0	0
38.	0	0	92.68	0	0
39.	0	0	95.12	0	0
40.	0	0	97.56	0	0

a/ N = Number years record = 40. n = Rank in order of highest magnitude.

Table B-6

Annual Draft-On-Storage Needed for Water Quality Control Below Kaw Reservoir
(acre-feet)

Year and Condition	Percent of Time Water Quality is Protected		
	95%	90%	80%
2020			
Condition A	8,200	2,800	--
Condition B	6,200	1,700	--
2070			
Condition A	13,000	7,500	--
Condition B	12,000	5,000	--

APPENDIX C

Benefit Calculations

1. The most likely alternative to the proposed Kaw Reservoir project for municipal and industrial water supply purposes is a single-purpose reservoir at the same site.

Total cost of a project to yield 167 mgd	$47,653,000*
Year of first need	1985
Municipal Bonding Period (years)	25
Equivalent Annual Cost, Amortizing at a Non-Federal Interest Rate of 4%	
$47,653,000 x 0.06401	$ 3,050,300
Federal Investment to Provide the Above Annual Payment at 3 1/8%	
$3,050,300 x 17.17308	$52,383,000
Equivalent Annual Cost Amortizing at a Federal Interest Rate of 3 1/8% for the 100-year life of the project	
$52,383,000 x 0.032759	$ 1,716,000
Operation and Maintenance	$ 35,000
Major Replacements	$ 1,500
Total Annual Cost	$ 1,752,500
Present Worth (1970 Value) of Annual Benefit	
$1,752,500 x 0.630290	$ 1,104,600

2. For maintaining satisfactory stream quality below Kaw Reservoir the most likely alternative to flow regulation by the proposed project would be similar regulation by two small upstream reservoirs, Silverdale and Beaver.

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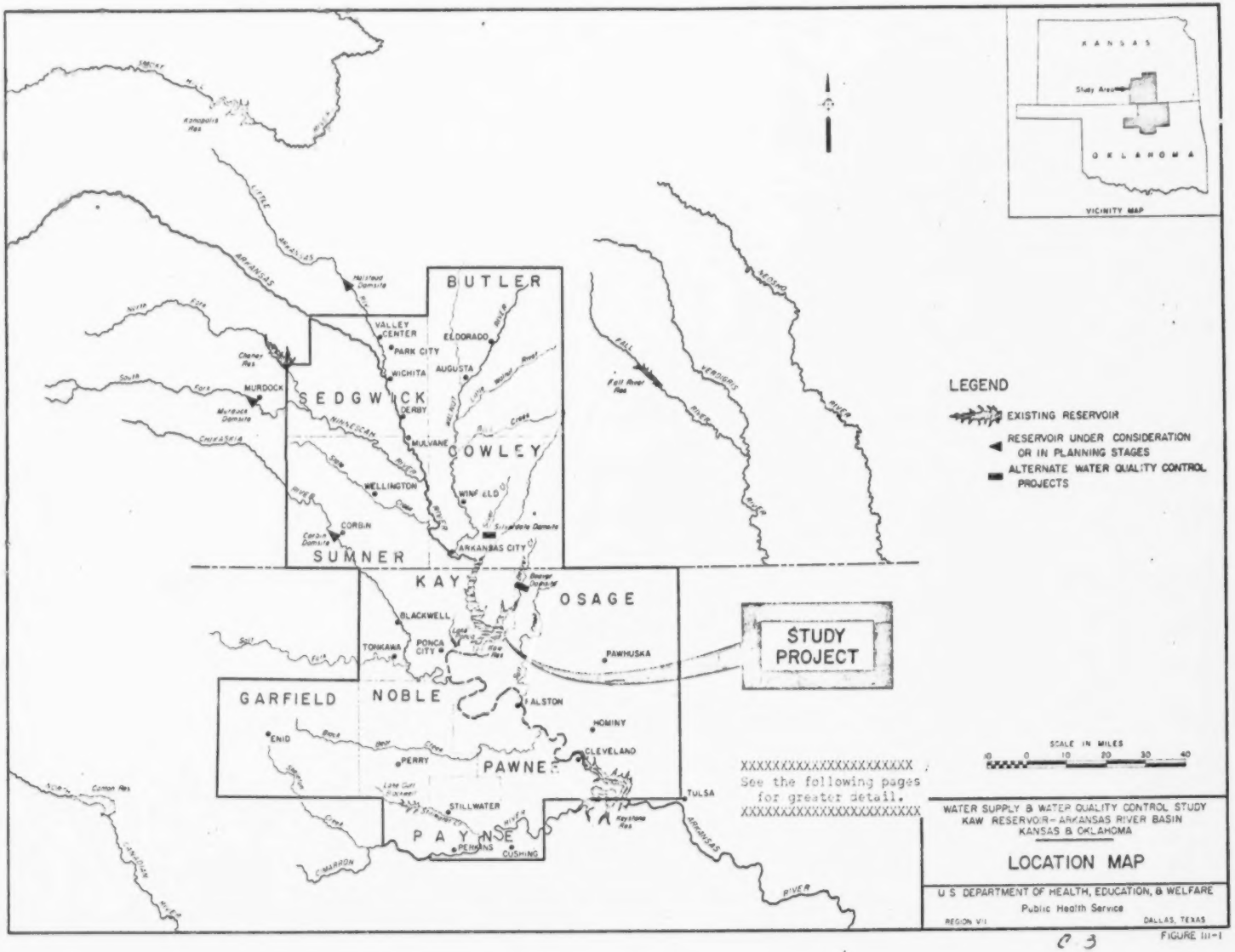
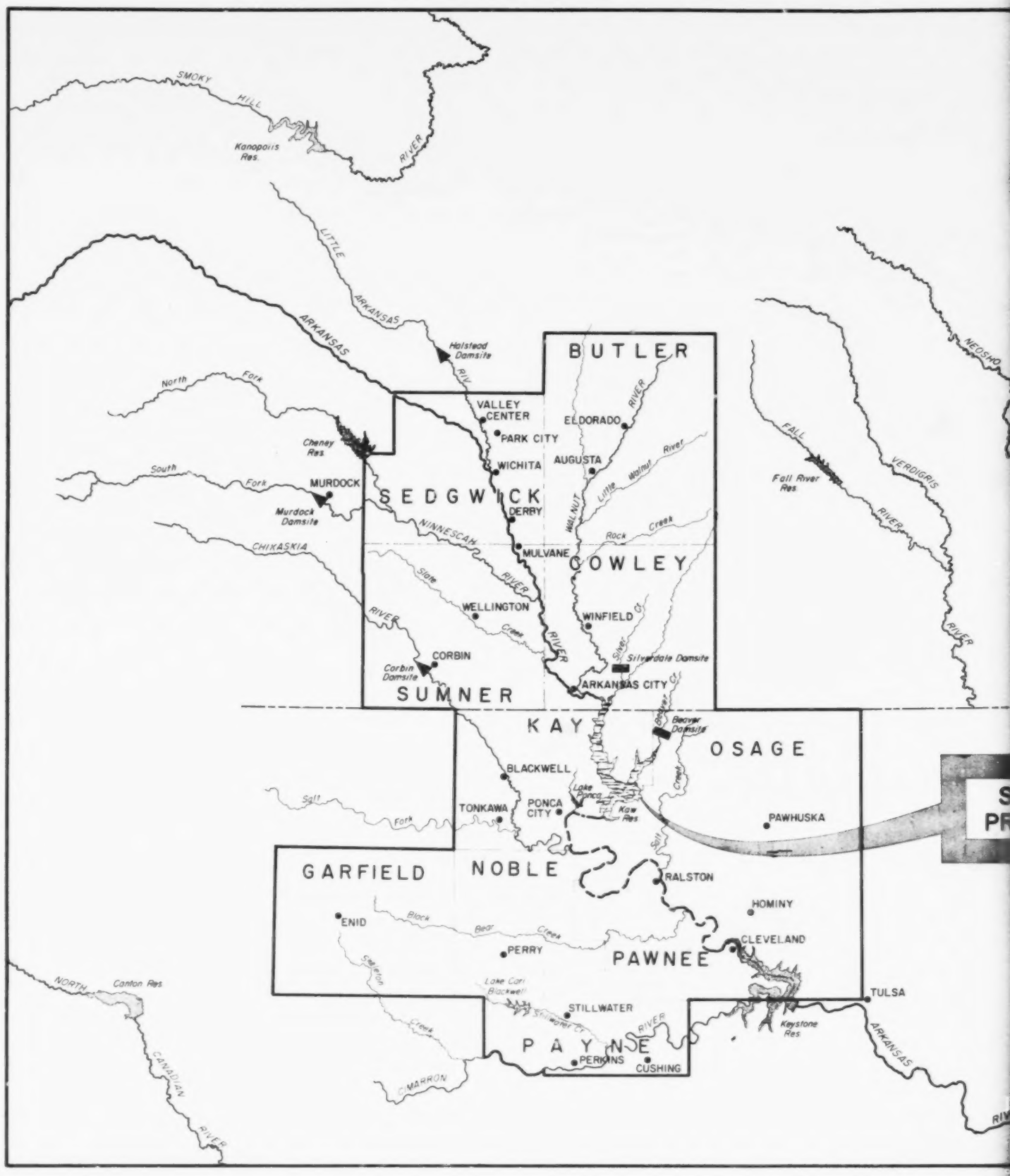
* Includes interest during construction.

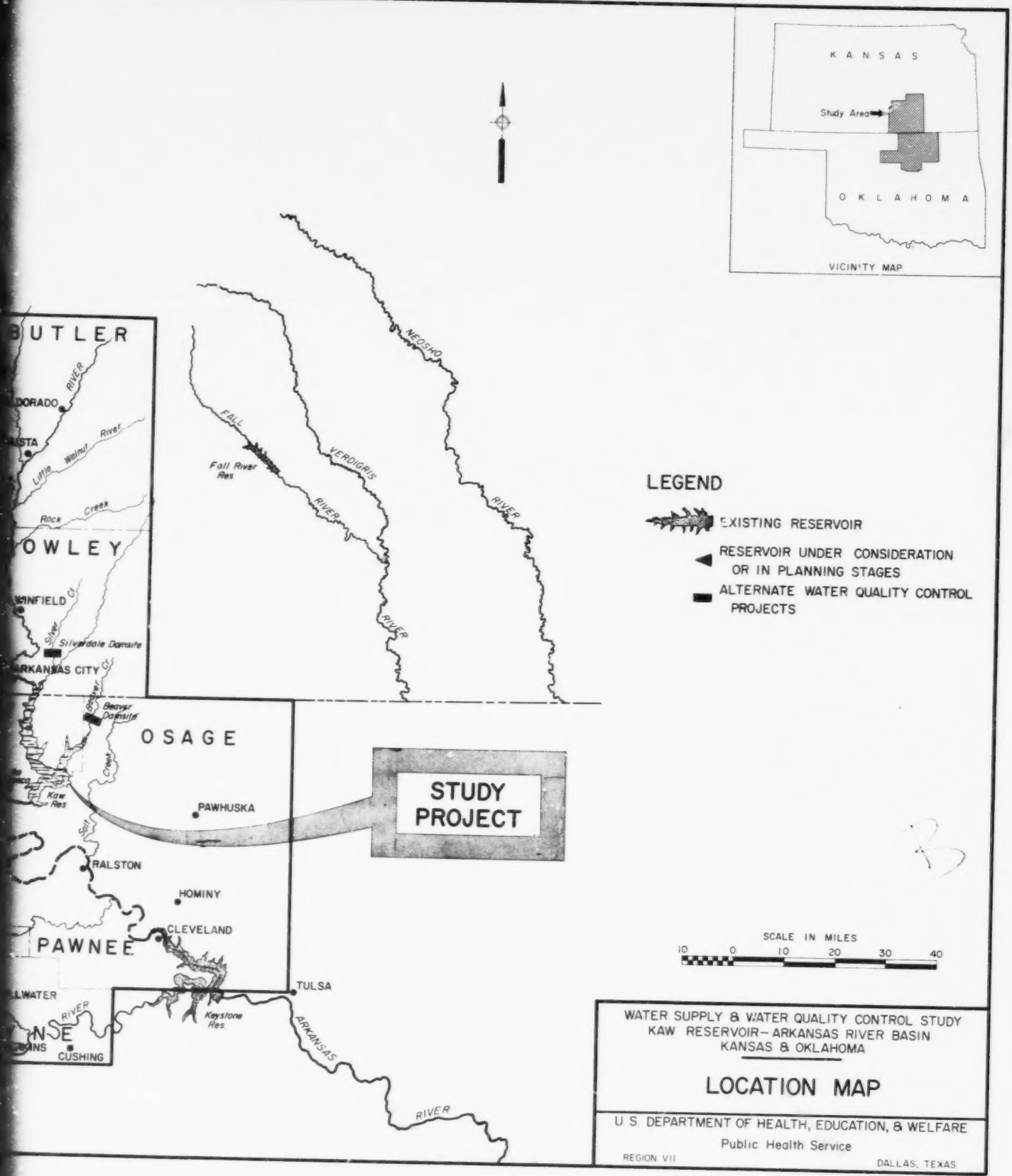
Silverdale Reservoir	
Total cost of a project to yield 6.5 mgd	$7,218,800*
Year of first need	1990
Equivalent Annual Cost, Amortizing at a Federal Interest Rate of 3 1/8% for the 100-Year Life of the Project	
$7,218,800 x 0.032759	$ 236,000
Operation and Maintenance	$ 29,000
Replacements	$ 200
Total Annual Cost	$ 265,200
Present Worth (1970 Value) of Annual Benefit	
$265,200 x 0.540407	$ 143,300
Beaver Reservoir	
Total cost of a project to yield 5.0 mgd	$6,393,800*
Year of first need	2000
Equivalent Annual Cost, Amortizing at a Federal Interest Rate of 3 1/8% for the 100-Year Life of the Project	
$6,393,800 x 0.032759	$ 209,000
Operation and Maintenance	$ 29,000
Replacements	$ 200
Total Annual Cost	$ 238,200
Present Worth (1970 Value) of Annual Value of Benefit	
$ 238,200 x 0.397266	$ 94,600
Average Annual Value (both projects)	$ 503,000
Present Worth of Total Average Annual Value	$ 238,000

* Includes interest during construction.


KANSAS
Study Area
OKLAHOMA
VICINITY MAP
BUTLER
SEDGWICK
COWLEY
SUMNER
KAY
OSAGE
GARFIELD
NOBLE
PAWNEE
PAYNE
VALLEY CENTER
PARK CITY
WICHITA
EL DORADO
AUGUSTA
DERBY
MULVANE
WELLINGTON
WINFIELD
ARKANSAS CITY
CORBIN
MURDOCK
BLACKWELL
TONKAWA
PONCA CITY
PAWHUSKA
ENID
PERRY
ALSTON
HOMINY
CLEVELAND
TULSA
STILLWATER
PERKINS
CUSHING
STUDY PROJECT
LEGEND
EXISTING RESERVOIR
RESERVOIR UNDER CONSIDERATION OR IN PLANNING STAGES
ALTERNATE WATER QUALITY CONTROL PROJECTS
XXXXXXXXXXXXXXXXXXXXX
See the following pages for greater detail.
XXXXXXXXXXXXXXXXXXXXX
SCALE IN MILES
10 0 10 20 30 40
WATER SUPPLY & WATER QUALITY CONTROL STUDY
KAW RESERVOIR - ARKANSAS RIVER BASIN
KANSAS & OKLAHOMA
LOCATION MAP
U S DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII
DALLAS, TEXAS
FIGURE III-1

C 3


SMOKY HILL RIVER
Kanopolis Res.
LITTLE ARKANSAS RIVER
ARKANSAS RIVER
Halstead Damsite
North Fork
Cheney Res.
South Fork
MURDOCK
Murdock Damsite
CHIKASKIA RIVER
BUTLER
VALLEY CENTER
PARK CITY
WICHITA
ELDORADO
AUGUSTA
RIVER
Walnut River
Little Walnut
SEDGWICK
DERBY
WALNUT
Rock Creek
NINNESCAH RIVER
MULVANE
COWLEY
Slate Creek
WELLINGTON
WINFIELD
Silver Cr.
Silverdale Damsite
CORBIN
Corbin Damsite
ARKANSAS CITY
Beaver Cr.
SUMNER
KAY
Beaver Damsite
OSAGE
BLACKWELL
Lake Ponca
Salt Fork
TONKAWA
PONCA CITY
Kaw Res.
PAWHUSKA
Salt Cr.
GARFIELD
NOBLE
RALSTON
HOMINY
ENID
Black Bear Creek
CLEVELAND
PERRY
PAWNEE
Skeleton Creek
Lake Carl Blackwell
TULSA
NORTH Canton Res.
STILLWATER
Stillwater Cr.
Keystone Res.
ARKANSAS RIVER
PAYNE
PERKINS
CUSHING
CANADIAN RIVER
CIMARRON
NEOSHO
FALL RIVER
Fall River Res.
VERDIGRIS RIVER


KANSAS
Study Area
OKLAHOMA
VICINITY MAP
BUTLER
RIVER
DORADO
Little Walnut River
Rock Creek
OWLEY
WINFIELD
Silverdale Damsite
ARKANSAS CITY
Beaver Damsite
OSAGE
Kaw Res
PAWHUSKA
Salt Creek
RALSTON
HOMINY
CLEVELAND
PAWNEE
TULSA
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U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
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FIGURE III-1